EML 4905 Senior Design Project

A B.S. THESIS
PREPARED IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE DEGREE OF
BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

SOLAR AND WIND HYBRID POWER SYSTEM

Final Report

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April 14, 2015

This B.S. thesis is written in partial fulfillment of the requirements in EML 4905. The contents represent the opinion of the authors and not the Department of Mechanical and Materials Engineering

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Andre Siuffo, Kevin Gregorio, and Marisol Contreras and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

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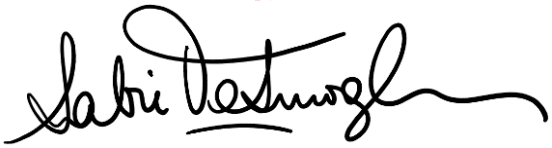

Dr. Tosunoglu

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Abstract

The purpose of this project was to design a portable and low cost power system that combines both wind electric and solar electric technologies. This system will be designed in efforts to develop a power solution for remote locations such as rural and research areas as well as improve the general well-being of individuals in developing countries affected by natural disasters. For this reason, it is imperative to design a hybrid system that will deliver a minimum of 1,500 watts of continuous power which is enough to power a wide range of appliances and medical equipment.

Introduction

1.1 Problem Statement

If any phrase were to be used to describe the time in which we are living, it would be "renewable energy." For decades now, this term has caused many businesses to design and manufacture products in efforts of promoting this phrase. The cost and ease of transportation, however, is the biggest problem these companies are facing.

For the past few years, new companies have been developing small power systems that can be used in locations where there is no electricity or in locations that suffer constant power outages. Different from a generator which is too heavy, too loud and requires fuel these companies are focusing on small hybrid systems that use only the sun and the wind to generate electricity. Unlike a generator, a hybrid system uses clean energy, runs quietly and can be easily transported when compared to standard systems [1].

Looking from the consumer perspective the cost of a hybrid system is still the biggest problem which can cost anywhere between $5,000 to $10,000 dollars. Considering that a portable hybrid system is designed to deliver a limited amount of power, less than 1.5 kW-hr, this is a high price for such system. In order for this system to become more attractive to the public, we need to design and develop a product which will benefit their pockets.

1.2 Motivation

In efforts to stimulate current businesses, we will be designing a portable “hybrid” electric system that combines both wind electric and solar electric technologies. This hybrid system will be designed to deliver 1,500 watts of continuous power which is enough to power a wide range of domestic appliances and medical equipment. This system will be an ideal power solution for remote areas such as small villages and research areas.

1.3 Literature Survey

As the world becomes more concerned about its environment, pollution and energy, countries are beginning to switch to renewable energies. Energy is essential to us to ensure our quality of life but the increasing cost of energy and environmental concerns are necessary to look for alternative sources. We will evaluate two systems, solar panel systems and solar and wind hybrid system (our system).

A small solar panel system can be a reliable and pollution-free producer of electricity for a home or office and is cost-effective. Several companies offer these off the shelf such as SunPower Corporation or SunForce Products Inc. These products are affordable and use both direct and scattered sunlight to create electricity to the home. However, the amount of power generated by this system depends on how much of the sun's energy reaches it. Thus, it works best in the southwestern United States, which receives the greatest amount of solar energy.

Hybrid power systems, which use solar and wind are an increasingly preferred alternatives for several reasons. In much of the United States, wind speeds are low in the summer

when the sun shines brightest and longest. The wind is strong in the winter when less sunlight is available. Because the peak operating times for wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce power when you need it.

Products	Daily Power Generation (watt - hour)	Voltage Produced (V)	Current (Amps)	Use	Cost	Warranty (years)
FIU Hybrid (Solar/wind) system	1500	18	4.5	Sunlight and Wind	$1,500	TBD
Sunpower Corporation: Model # 37186 850 Watt system	850	17	5	Direct Sunlight Only	$3,500	25
SunForce Products Inc: Model # 39810: 10 panels at 80 watts each	800	17.3	4.67	Direct Sunlight Only	$3,200	25

Table 1 Product Specification Comparison

Our hybrid systems are stand-alone systems, which operate "off-grid" -- not connected to an electricity distribution system. For the times when neither the wind nor the solar systems are producing, our hybrid system can provide power through batteries and/or an engine generator. In conclusion, a small “hybrid” electric system that combines wind and solar technologies can offer several advantages over either single system.

Project Formulation

2.1 Design Purpose

The purpose of this project is to design a portable and low cost power system that combines both wind electric and solar electric technologies. This hybrid system will be designed to deliver 1500 watts of continuous power which is enough to power a wide range of appliances and medical equipment.

The system is composed of a wind generator, a solar panel, a charge controller, a battery and an inverter. The solar panel and wind turbine work in tandem to charge a battery via a controller. After, an inverter will be used to convert DC power from the battery into AC power suitable for domestic use. The system will have a battery bank large enough to supply electric load for two days.

2.2 Project Objectives

The main objective of this project is to provide an alternative power solution for remote locations such as research areas and small villages. Also the system can be used as a temporary power solution for locations affected by natural disasters. In order to reach these objectives the product must be low cost and easy to manufacture.

2.3 Addressing Global Design

In order for this product to be a success amongst all types of users, there are many global design concepts which must be addressed and implemented. These types of design implementations are usually the ones that get the most overlooked, but we understand its importance and believe that it actually serves as the base of our project idea. The idea for this project came to mind when we realized the energy crisis which many developing nations around the globe are facing. In order for this product to improve the general well-being of these individuals, we believe it necessary and essential to incorporate the following key global design components:

- Design for manufacturability in different parts of the world
    - We understand that some materials and component sizes may not be readily available in some markets, and at times may take weeks or even months to source. In order to avoid these types of situations a design with easy to source components both locally and internationally will be developed.
- Multi-lingual user's manual and assembly instructions
    - In order to provide temporary relief to locations affected by natural disasters in an effective and efficient manner, a user's manual and as well as assembly instructions will be provided to the individuals in the following languages: English and Spanish.
- Warning labels

- This product consists of both mechanical and electrical components, thus, labels in multiple languages and graphical warnings will be implemented to the structure in order to prevent personal injury.

The use of the aforementioned global design components is essential to having a successful product. For this reason, a great deal of time and effort has been put into their development.

Project Management

3.1 Project Timeline

In order to maximize the efficiency of the team and ensure that significant advances towards the completion of the project are being made a project time line was created. This project was initiated towards the end of August and is expected to be completed by early to mid-April. As visible from the chart, the most time for completion of this project went into design research. This was done specifically to ensure that the final product being produced was of excellent quality and durability.

	August	September	October	November	December	January	February	March	April
Project Formulation									
Literature Survey									
Design Research									
Conceptual Design									
Initial Design									
CAD Drawings & Simulation									
Material Selection / Costing									
Part Acquisition / Assembly									
Product Testing / Analysis									
Final Design									

Table 2 Project Timeline

3.2 Team Responsibilities

It is imperative to have specific project responsibilities assigned to each individual team member. The way in which the responsibilities for this project where delegated can be seen from the table below.

	Andre Siuffo	Kevin Gregorio	Marisol Contreras
Project Formulation			
Literature Survey	SUPPORT	SUPPORT	
Design Research			SUPPORT
Conceptual Design			
Initial Design			SUPPORT
CAD Drawings & Simulation			SUPPORT
Material Selection / Costing	SUPPORT		
Assembly			SUPPORT
Product Testing / Analysis		SUPPORT	
Final Design			

Table 3 Team Responsibilities

As visible from the table of team responsibilities, no one team member was a responsible for an individual task. At least two members have been assigned the responsibility of completing a specific task while the third member served a support role in the process. This breakdown method proved to be effective in completion of the project.

Material Selection

4.1 Electric Motor Selection

The selection of the motor is the most important part of any wind turbine system. There are many industrial motors in the market that can be used as a wind generator. When selecting a motor it is very important to choose a motor that is capable of producing the battery voltage at low RPM.

Permeant Magnet Motors are considered the best choice for small wind turbines since they are widely available, inexpensive and require low RPM to start producing electricity. There are Permanent Magnet Motors that generates either AC or DC current and they both can be used in wind turbines. Permanent Magnet Motors with an AC output are called Permanent Magnet Alternator (PMA) and are considered more efficient then motors with DC output.

There are different types of Permanent Magnet Alternators. Automotive Alternators are not recommended to be used in wind turbines since it requires high RPM to generate useful amounts of power. The motor selected for this design is called Freedom PMG™ made by Missouri Wind and Solar. This motor was designed to be used in small wind turbines, and it will start producing the battery voltage at considerably low RPM.

Figure 1 Freedom PMG - Brushless Permanent Magnet Generator [2]

The advantages of using the selected motor in comparison to other available motors in the market are as follows:

- Battery voltage production begins at approximately 266 RPM
- No cogging and easy to rotate – Cut in speed of 6 MPH
- Skewed stator core with high grade electrical steel and heavy duty copper windings
- Extra thick polished aluminum case
- Zinc plated 14 rare earth neodymium magnet rotor
- No brushes to fail or replace
- Two heavy duty bearings located in the front and back

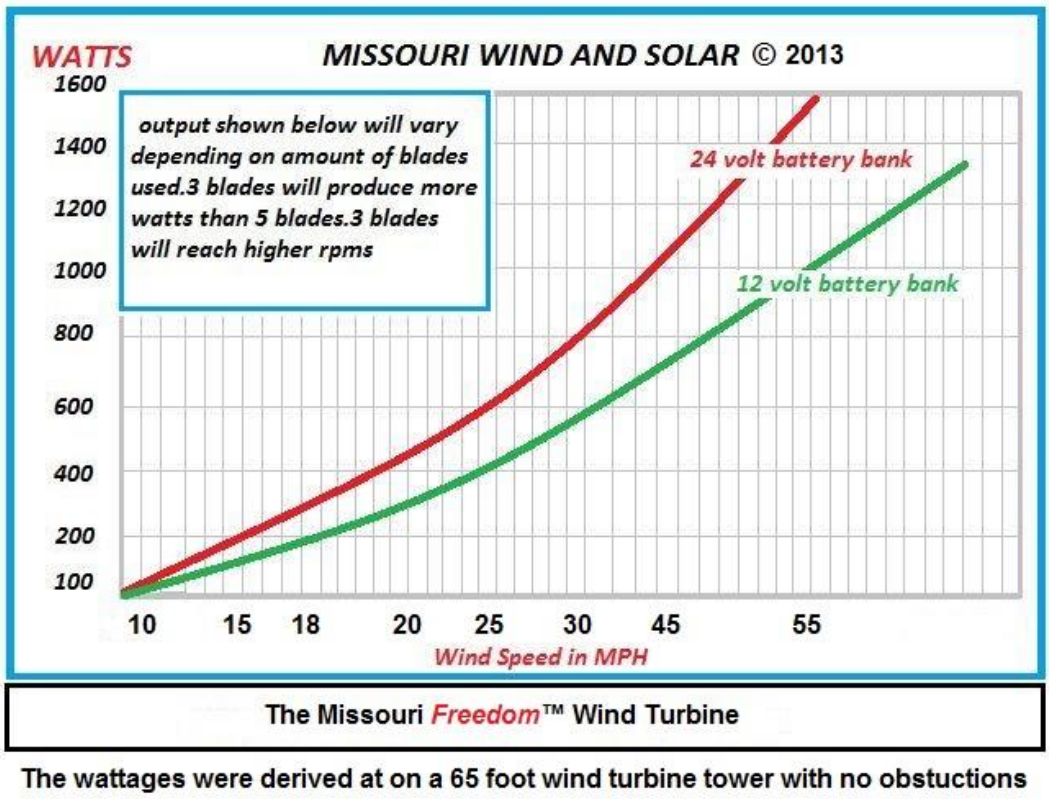


Figure 2 Freedom PMG Watts vs Wind Speeds [3]

In order to charge a standard 12 Volts battery, 14-16 Volts are need. The freedom PMG™ is designed to start producing enough voltage to charge a battery at approximately 266 RPM. For this design, we will assume that this hybrid system will be used in areas with an average wind speed of 10 mph blowing for at least ten hours a day. From the graph above, which represents the power generation of the Freedom PMG™, we can get a rough estimate of how much power this motor will produce in a single day.

$$Daily\ Power\ Generation: 100\ Watts\ \times 10\ \not{hours}\ \approx 1{,}000\ watt \cdot \not{hour}$$

4.2 Solar Panel Selection

For this design, we will be using a solar a 100w Solar Panel made by Renogy. Renogy uses top quality solar cells and superior accessories to produce high performance solar modules.

Figure 3 Renogy 100 Watt Monocrystalline Solar Panel [4]

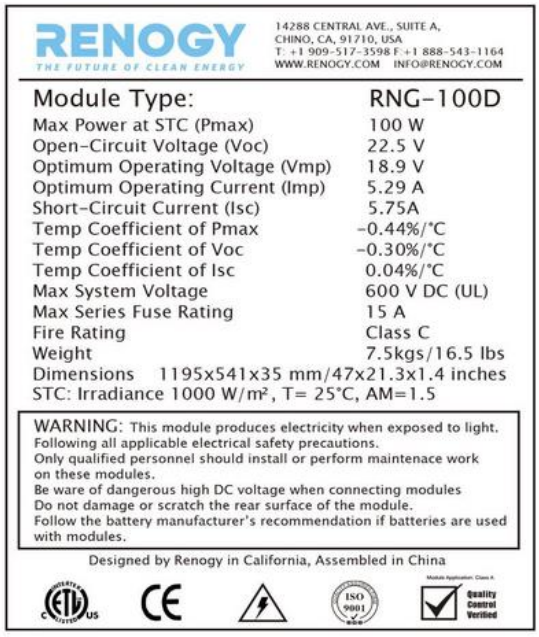

RENOGY
THE FUTURE OF CLEAN ENERGY
14288 CENTRAL AVE., SUITE A,
CHINO, CA, 91710, USA
T: +1 909-517-3598 F: +1 888-543-1164
WWW.RENOGY.COM INFO@RENOGY.COM
Module Type: RNG-100D
Max Power at STC (Pmax) 100 W
Open-Circuit Voltage (Voc) 22.5 V
Optimum Operating Voltage (Vmp) 18.9 V
Optimum Operating Current (Imp) 5.29 A
Short-Circuit Current (Isc) 5.75A
Temp Coefficient of Pmax -0.44%/°C
Temp Coefficient of Voc -0.30%/°C
Temp Coefficient of Isc 0.04%/°C
Max System Voltage 600 V DC (UL)
Max Series Fuse Rating 15 A
Fire Rating Class C
Weight 7.5kgs/16.5 lbs
Dimensions 1195x541x35 mm/47x21.3x1.4 inches
STC: Irradiance 1000 W/m², T= 25°C, AM=1.5
WARNING: This module produces electricity when exposed to light.
Following all applicable electrical safety precautions.
Only qualified personnel should install or perform maintenace work on these modules.
Be ware of dangerous high DC voltage when connecting modules
Do not damage or scratch the rear surface of the module.
Follow the battery manufacturer's recommendation if batteries are used with modules.
Designed by Renogy in California, Assembled in China
ISO 9001
Quality Control Verified

Figure 4 Renogy 100 Watt Monocrystalline Solar Panel Specifications [5]

The maximum power of this solar panel is 100 W. Considering that this system will be used in areas with at least five hours of strong sunlight this panel will produce at least 500 watt-hour in a single day. Now we can estimate how much power this whole system will produce.

Component	Watt-hours (Wh) per Day
Wind Turbine	1,000
Solar Panel	500
Total Power Generation	1,500

Table 4 Total System Power Generation

According to our estimation this hybrid system will produce an average of 1,500 watt-hour daily. This estimate is based on ideal conditions such as no obstruction to the wind turbine and clear skies for the solar panels.

4.3 Battery Bank Sizing

For this deign we will be using two deep cycling marine battery connected in parallel. Marine batteries are considering a good choice for renewable energy systems.

Figure 5 EverStart Deep Cycling Marine Battery [6]

Selection of this battery was based on the following specifications:

- Applications: Starting, trolling, RV, deep cycling
- 12-volt battery
- 115 amp hour rating
- 160 minutes reserve capacity
- 65 repetitive reserve capacity
- 750 cranking amps
- 675 cold cranking amps
- Dimension: 12 7/8” x 6 3x4” x 9 1x2”

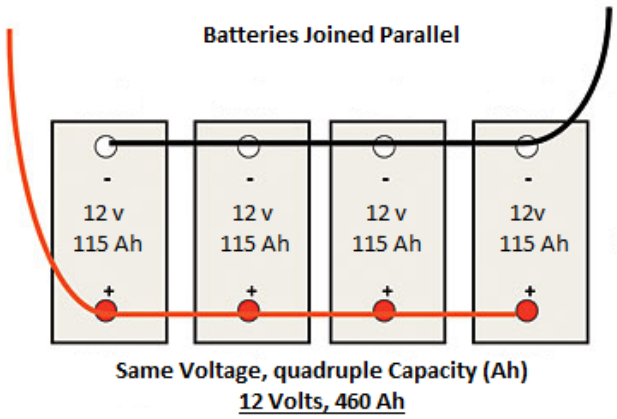


Figure 6 Parallel Wiring Diagram

The storage capacity of the batteries has to be increased in order to have a more efficient system. By connecting the batteries in parallel the following storage capacities were calculated based on the usage of two and four batteries.

Storage capacity with two batteries:

$$Storage\ Capacity = 12V\ \times 2{,}30Ah = 2{,}760\ W \cdot hr$$

Storage capacity with four batteries:

$$Storage\ Capacity = 12V\ \times 4{,}60Ah = 5{,}520\ W \cdot hr$$

For this design, we will be using two batteries connected in parallel so the voltage will remain the same and the amperage will increase two times. This battery bank will have a total capacity of 2,760 watt-hour, however, the system is designed to use only 1,500 watt-hour (54% of bank capacity). By using only 54% of the battery bank capacity the useful life of the batteries will increase dramatically so we can expect these batteries to last a long time. The remaining 46% will serve as a reserve and will be consumed when the system is not generating enough power.

4.4 Charger Controller Selection

For this design, we will be using a charge controller that is made for solar and wind hybrid systems. This controller will serve to maintain the proper charging voltage on the batteries. The controller has one output for the battery bank and two imputs; one for the solar panel and one for the wind turbine.

Figure 7 Charger Controller [7]

4.5 Wind Blades Selection

When selecting the blades for a wind turbine there are some important factors that must be considered in order to ensure durability safety and performance. The first important factor is the material of the blade. That several types of materials used in small wind blades such as aluminum, carbon fiber, plastic and even PVC. PVC is not considered a good choice for blades since they can fracture and even explode at high wind speeds.

Aluminum is considered a good material, however, most of the aluminum blades available in the market have a large pitch. The advantage of a large pitch is that the blades will start spinning at low wind speeds, however, at about 15 mph wind speed it creates a “blocking” effect

and it stops spinning. This “blocking” effect is caused by the large pitch which acts like a wall at high wind speeds. There are some exceptions, and it is possible find some well-made aluminum blades with a small pitch which can be considered a good choice.

Carbon fiber and some custom plastic compounds are considered great materials for small wind blades. Most of the carbon fiber and custom plastic blades in the market have an airfoil shape which is similar to an airplane wing. This airfoil design creates a perfect pitch providing less resistance against the wind; therefore, they can handle high wind speeds. For this design, we will be using a blade that is made from high quality custom plastic compound that has the ability to resist impact, weathering, moisture and UV rays.

The second important factor that must be considered in a wind generator is the size of the blades and the number of blades. Giant blades, which are seen in wind farms, have a rotor diameter ranging from 160 ft to 400 ft and are rated at 50 kW to 5,000 kW which is enough to power a small neighborhood. When talking about micro portable power systems, it is not possible to use a giant blade and the power produced is limited to around 2 kW. Most of the wind blades available in the market, for small power systems, have a rotor diameter of approximately 60 inches and comes in configurations of two to seven blades. The number of blades will depend on the average wind speed in the area where the system will be used. For example, many designs with three blades requires at least 12 mph wind start spinning, on the other hand, a turbine with seven blades will start spinning at about 7 mph wind. The main idea of a wind generator is to archive constant power production so if the wind generator is being installed in an area with low wind, it is better to have more blades.

Wind turbine blade design an extensive and complex topic. This report only provides a general idea about how to select wind blades for micro power systems .The actual start up speed will highly depend on the design of the blade and the generator. For this system, we decided to go with a five-blade design, however, we will not assume any data provide by the manufacturer and the actual start up speed of this blade will be experimentally measured and included in this appendix of this report.

Figure 8 Wind Turbine Blades [8]

4.6 Electrical Wiring

In order to connect the electrical components of any solar and wind energy system, it is important to use the correct wire size to prevent overheating and loss of energy. There are four important connections in this system; the connection from the wind turbine and solar panel to

the charge controller, the connection from the charge controller to the input terminals of the battery, the connection from one battery to the next battery and finally the connection from the output terminals of the battery to the power inverter.

Since we selected a motor that generates a 3-phase AC current, power loss is not a big concern; when compared to motors with DC output. Alternating current AC does not require large cables to carrier the load, so basically a 12 American Wire Gauge (AWG) wire is capable of carrying the load up to 100 ft with nearly no power loss. So for the connection between the generator and the charge controller, we will use a high quality 12 AWG wire that is water and sunlight resistant.

The easiest way to select the appropriate wire for the solar panel is by using a chart that shows the require wire size to achieve 3% or less voltage drop. Below is a chart showing the required wire size to connect the solar panel to the charge controller. The top row represents the AWG, the column represents the number of amps the solar panel is rated at and the grid cells show the distance between the solar panel and the controller.

	#12	#10	#8	#6	#4	#3	#2	#1	#1/0	#2/0
4	22.7	36.3	57.8	91.6	146	184	232	292	369	465
6	15.2	24.2	38.6	61.1	97.4	122	155	195	246	310
8	11.4	18.2	28.9	45.8	73.1	91.8	116	146	184	233
10	9.1	14.5	23.1	36.7	58.4	73.5	92.8	117	148	186
12	7.6	12.1	19.3	30.6	48.7	61.2	77.3	97.4	123	155
14	6.5	10.4	16.5	26.2	41.7	52.5	66.3	83.5	105	133
16	5.7	9.1	14.5	22.9	36.5	45.9	58	73	92	116
18	5.1	8.1	12.9	20.4	32.5	40.8	51.6	64.9	81.9	103
20	4.6	7.3	11.6	18.3	29.2	36.7	46.4	58.4	73.8	93.1
25	3.6	5.8	9.3	14.7	23.4	29.4	37.1	46.8	59.1	74.5
30	3.1	4.8	7.7	12.2	19.5	24.5	30.9	38.9	49.2	62.1
35	2.6	4.2	6.6	10.5	16.7	20.9	26.5	33.4	42.2	53.2

40	2.3	3.6	5.8	9.2	14.6	18.4	23.2	29.2	36.9	46.5

Table 5 Solar Panel Wire Size

The solar panel selected for this system is rated at 5.29 A (Imp). Considering that this panel will be at a maximum distance of 30 ft from the charge controller, a 10 AWG wire is ideal.

When connecting the charge controller to the batteries, as long as the controller is close to the batteries, it is not required to use a large wire. For instance, it is acceptable use the same wire size used for the solar panel. So for this connection we will use the same 10 AWG wire used for the solar panel connection.

Finally, the connection between batteries and from the battery output to the inverter requires a very large cable. Usually the correct wire size is indicated on the inverter's manual but is also safe to use the following table. The top row indicates the distance between the batteries and the inverter, the column represents the maximum power output of the inverter and the grid cells indicate the ideal wire size (AWG).

Inverter Size	**< 3 ft**	**3ft - 6ft**	**6ft - 10ft**
400 Watts	8	6	4
750 Watts	6	4	2
1000 Watts	4	2	1/0
1500 Watts	2	1	3/0
2000 Watts	1/0	2/0	250
2500 Watts	1/0	3/0	350
3000 Watts	3/0	4/0	500

Table 6 Inverter Wire Size

Since the minimum power output of the inverter selected for this system is 1600W and considering that the inverter will be located less than 3ft from the battery, a 3 AWG wire is ideal.

4.7 Battery Box

In any off-grid energy system is important to select an appropriate location to install the batteries and other electrical complements. This location must be protected from the rain and have proper ventilation. The purpose of this project was to design a system that is portable and for this reason we decided to adapt a heavy duty wheeled tool box to install the batteries and electrical components. This toolbox will provide perfect protection from the weather and it will be easy to move around since it has wheels. A powerful fan will be added to the tool box in order to remove the heat generated the by electrical components.

Figure 9 Portable Tool Box [9]

Prototype Construction

5.1 Frame Design

What makes this product standout over existing portable wind turbines is its innovative tower design. The main focus in developing the wind turbine was to give the user the capability to adjust the wind turbine to a desired height, 10 to 15 feet. This idea came after reading through various comments criticizing the design of portable wind turbines. Current products in the market come with a tower at a set height which limits the usage and efficiency of the product depending on the site of installation. If these products are not placed in an open space, clear of any obstructive structure (home, cars, tents, trees, etc.) their efficiency will suffer due to the high turbulence that it will experience.

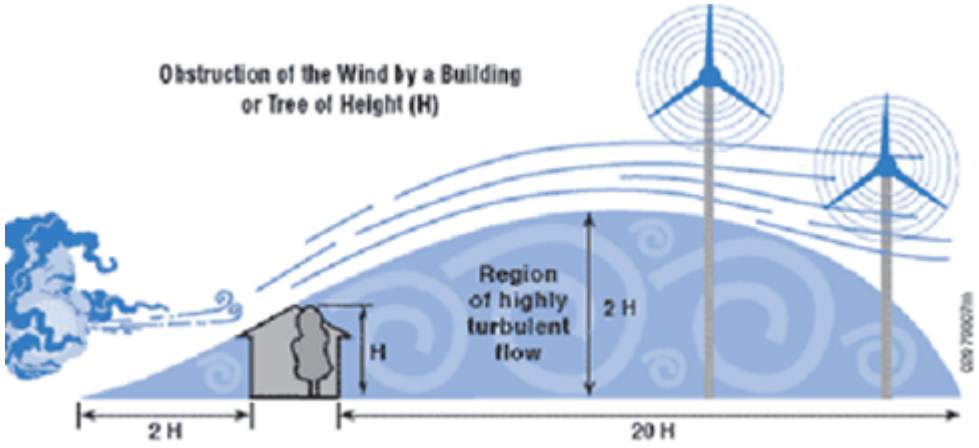


Figure 10 Turbulence Region

Turbulence is the result of random and continuous changing air motions. This type of wind motion will not allow the blades of the wind turbine to rotate in a smooth effective and efficient manner. For this reason, it is recommended to install and operate wind turbines in optimal

locations. Figure 10 depicts the area of high turbulence near a building or tree of height H. Current market products do not give the flexibility for the user to easily increase the height of the system to clear this area of high turbulence that may be caused by small trees and bushes. Location and placement of a wind turbine is crucial with any wind turbine, as small differences in wind speed may have a huge impact on the performance of any electric system.

The designed tower aims at increasing the turbine's efficiency by clearing areas of high turbulence. This was accomplished by implementing a cranking mechanism, similar to those found on parasols, which would raise a section of the tower to an optimal height. After researching methods of converting rotational motion (crank) to linear motion (tower height change) the following components were found to be of best use for the system: a gearbox, lead screw, stainless steel tubing, and crank handle. In addition to this, it was necessary to implement a pivot system for the turbine to rotate in order to adjust to any change in wind direction. Consequently, a pivot bracket, along with a slip ring for the wiring, center shaft and a tail was implemented to the design of the system.

Essentially, the most critical part of the designed solar and wind hybrid power system was the pivot system itself. It is very important for the wind turbine part of the system to be able to adapt to changing wind directions. The ability for such a system to perform such operation increases the products efficiency significantly. The figure below portrays the complete assembly of the pivot system. A breakdown of each of these components role and description will be provided in the latter.

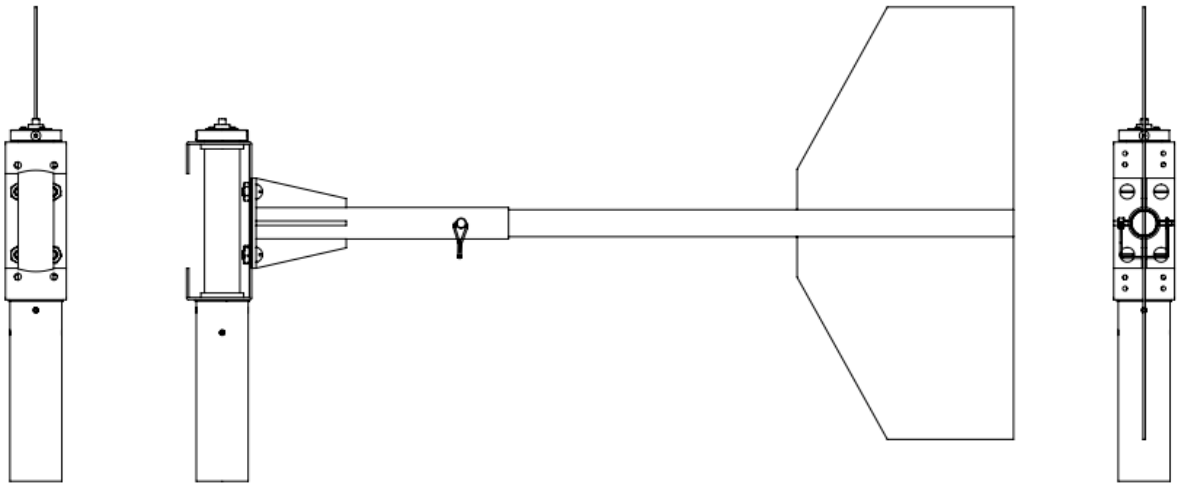


Figure 11 Pivot System - Front, Side, & Back View

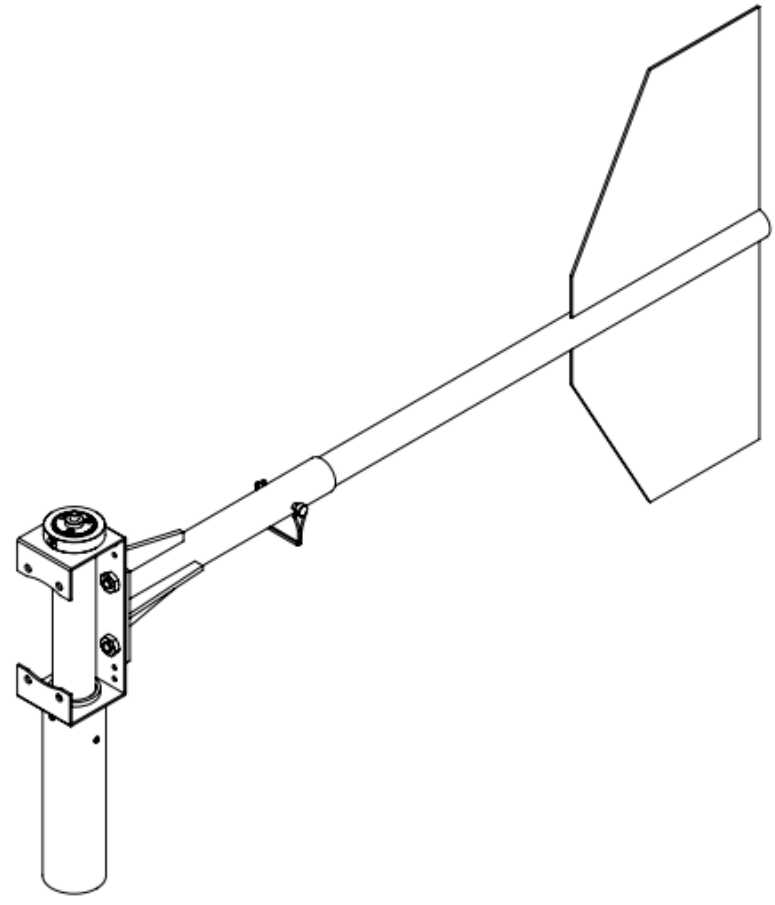


Figure 12 Pivot System

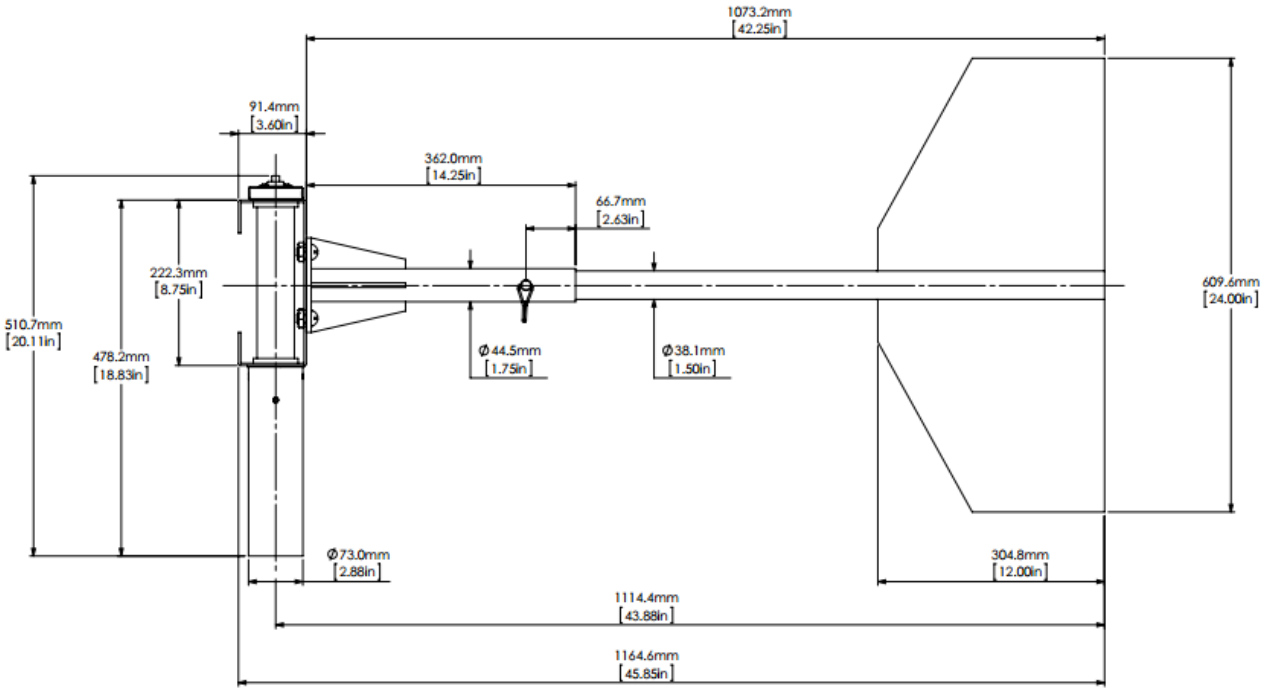


Figure 13 Pivot System – Side View Overall Dimensions

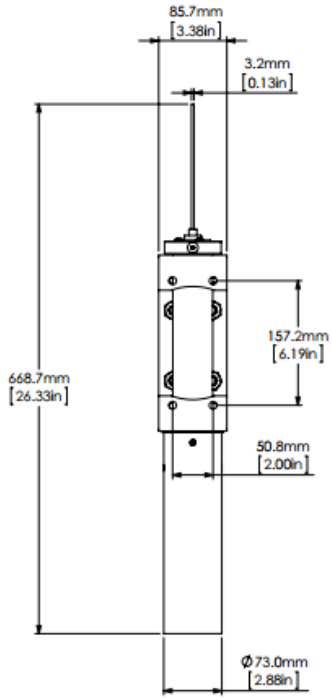


Figure 14 Pivot System - Front View Overall Dimensions

Bracket, Wind Turbine Pivot Bracket:

The pivot bracket which was designed for the hybrid system was made of 1/8” thick galvanized steel. The bracket was designed so that it would be able to enfold around a PVC center shaft and have the capability to hold the electric generator and tail assembly. Proper holes were drilled on the pivot bracket component so that it can be installed in whichever direction.

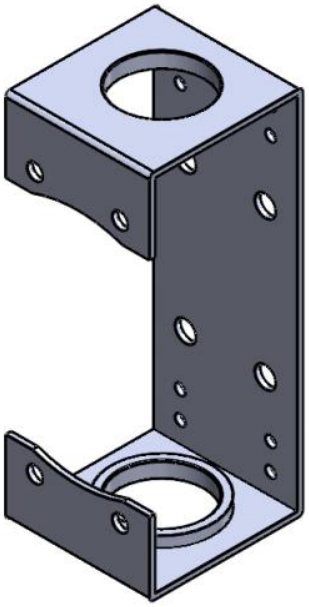


Figure 15 Bracket, Wind Turbine Pivot Bracket

Shaft, PVC Center Pivot Shaft:

A PVC center shaft was machined in order to hold the pivot bracket in its location. The PVC material was chosen intentionally in order to reduce the friction created by the contact of the pivot bracket. Initially, an aluminum pipe was being used but after conducting preliminary rotational testing, it was observed that the system did not rotate with ease. The center shaft was machined from a 2.50 in diameter PVC rod to fit into the inside diameter of the aluminum extrusion (2.875in OD x 0.203in WALL) being used as the main tower material. Once machined, this part was assembled into the aluminum extrusion and fastened by four 0.25in x 0.25in stainless steel split pins. The pivot bracket would then fit on the center shaft and be held in place by a ring shaped stopper made of delrin material and fastened on the PVC center shaft by two 1/4-20 x 1/4" flat head socket cap screws. The large threaded hole found on its side was machined

in order to assemble a cord grip so that the cable, which passes through its core, can be slipped out.

Figure 16 Shaft, PVC Center Pivot Shaft

Stopper, 2" ID x 2.80" OD Ring Stopper for Pivot Bracket:

The stopper serves as a lock so that the pivot bracket does not lift out of the center pivot shaft. This piece not only serves as a safety piece but was intentionally designed in a ring shape so that it did not interfere with the electrical wiring of the turbine which needed to run directly in through the top of the center shaft. The piece was machined out of delrin material, which was sourced at a local machine shop, and includes two countersink holes for 1/4 -20 Flat Head Socket Cap Screws that are used to fasten on the top of the center pivot shaft.

Figure 17 Stopper, 2" ID x 2.80" OD Ring Stopper for Pivot Bracket

Tower Pole, Top Portion of Tower:

The Pivot System assembly is held together by a 10 inch long 2.875in OD x 0.203in WALL Aluminum Extrusion. This piece serves as the base for the pivot system as it holds all the components together. The center pivot shaft assembles on this extrusion with the use of four 0.25in x 0.75in split pins which pass through the two top 1/4 inch holes on the extrusion. This top portion of the tower is also connected to a stainless steel square tubing that rides along a lead screw which transmits the rotational cranking motion of the user to linear motion. In simpler terms, this is the piece that displaces when the user is changing the total height of the system. The large hole on the side of the piece is used to pass the cord grip that connects to the PVC Center Pivot Shaft, so that the cable may come out of the pole and free to connect to the electrical power box located on the ground.

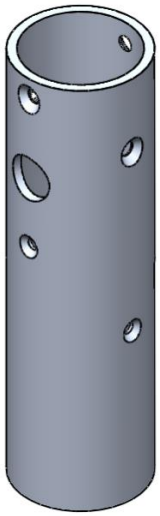


Figure 18 Tower Pole, Top Portion of Tower

Slip Ring:

The wiring of the system needed careful consideration because a rotation was playing a big role. In order for the system to function properly, rotate freely without the cable winding around the tower, a special component was sourced. After much research, it was concluded that the best way to go around this issue was to use a slip ring – an electromechanical device which allows for the transmission of power and electrical signals from a rotating to a stationary structure. The slip ring, also known as electrical rotary joints and rotary electrical interfaces, used in the designed solar and wind hybrid power system is a 3 wire 15A 3 x 3 phase 360 degree rotation slip ring which was sourced from Techex Online.

Figure 19 15A×3 Slip Ring for Wind Turbine Generator 3 Phases

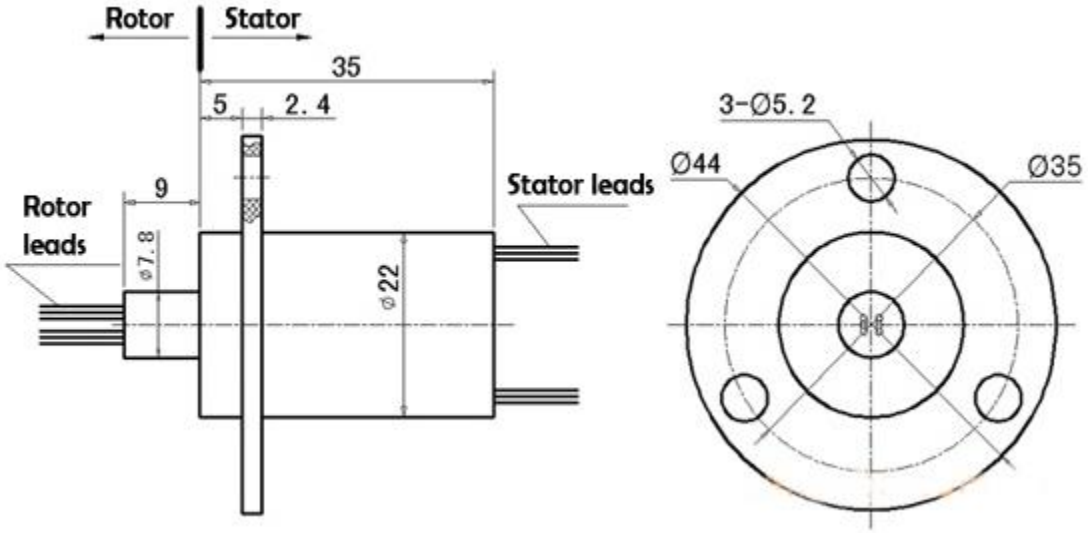


Figure 20 Slip Ring Dimensions

Holder, for Tail Boom:

The tail boom holder provides adds extra portability to the product. This part improves storage space by allowing the user to take apart the tail assembly from the center structure itself. It serves as a connecter for the tail and the pivot bracket which can be assembled with one another within seconds with the use of a provided wire lock. Assembly of tail boom holder on to the pivot bracket was also made simple so that any user can effortlessly put them together with the use of four 1/2-13 x 0.75in round head slotted machined screws.

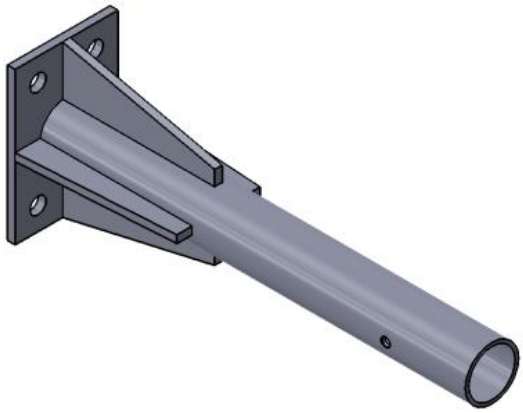


Figure 21 Holder, for Tail Boom

Tail Assembly:

In order for the pivot bracket assembly to serve its rotating function a tail was designed and implemented into the system. As is the case with other product tail assemblies, the tail consists of a boom and vane. The sizing and use of correct material was vital in the development of the tail. Tail boom length and vane surface area are important factors in having the wind turbine facing into the wind. If not sized accordingly, the turbine will want to shift away from the

direction of the wind causing a huge drop in RPM and power. The tail assembly used in the hybrid power system consists of a 42 inch tail boom and a 45 square inch tail vane.

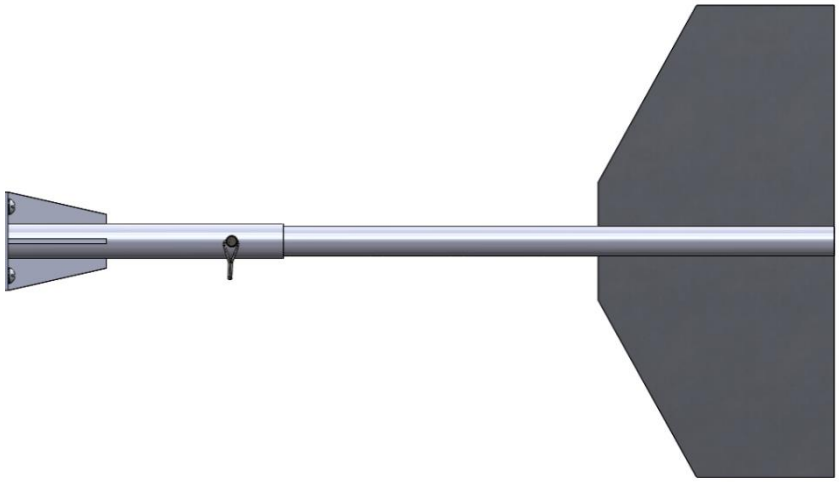


Figure 22 Tail Holder and Tail Boom & Vane Assembly

Wire Lock, 0.25" x 2.50" Steel Pin with Wire Lock, SS:

The key selling point of the Solar and Wind Hybrid Power System is its portability. For this reason, the tail assembly did not come permanently fixed on the pivot bracket itself. Instead, the user is given the task to simply insert the boom of the tail into the tail boom holder, line up the holes on the boom and the holder, and insert the provided wire lock. The wire lock that is being provided is a 0.25in x 2.50in Steel pin with a square wire lock. This piece was chosen over all other fasteners because of the installation ease it provides the user.

Figure 23 Wire Lock, 0.25" x 2.50" Steel Pin with Wire Lock, SS

As previously mentioned, the tower of the Solar and Wind Hybrid Power System was designed so that it is strong enough to take the loads being exerted by the wind's impact on the blades and the weight of the solar panel, which is being fastened on to the lower mid-section of the pole with the use of u bolts. In addition, a cranking mechanism was developed to overcome areas of high turbulence that are caused by nearby fences, trees, etc. In the section below, the components which make up the tower system are reviewed and explained.

Guide, Stainless Steel Tube Guide – 7", PVC:

The piece below is used to guide and stabilize the stainless steel center square tube that is used as the tower extension. A simplistic design, but a powerful and vital function in the performance of the system. As without it, when the tower is fully extended, the top portion of the tower would move back and forth because of its instability. The guide was machined to fit smoothly into the inside diameter of the tower pole and to guide the stainless steel tubing through its center in a secure manner.

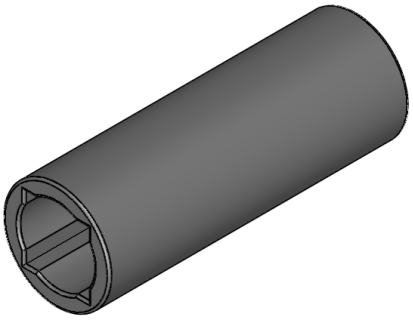


Figure 24 Guide, Stainless Steel Tube Guide – 7", PVC

Tower Pole, Bottom Portion of Tower:

The lower portion of the tower consist of a 105" aluminum (6061-T6) extrusion which was sourced from Eastern Metal with the help of a local manufacturing company, TUUCI. With the help of this company, it was possible to get exclusive pricing which is only available to customers buying extrusions in high volumes. Once cut to length, there is only minor operations needed to have the pole ready for assembly. The lower countersink holes that are present on the serve to hold the gearbox in place and as the input of the crank handle. The top two countersink holes are simply drilled in order to hold the stainless steel tubing guide in place.

Figure 25 Tower Pole, Bottom Portion of Tower

Extrusion Tube, Square 1.48 x 1.48 Tube, SS:

Having the Solar and Wind Hybrid Power System be capable of increasing in height with the simple motion of a crank is main due possible because of the load that is driven by the gearbox on to the leadscrew, which intron translates its rotational motion to the stainless steel tubing. The stainless steel tubing, rides up and down the towers leadscrew as the user turns the crank handle in any direction. A stop pin (hex nut) was welded on the lower face of the leadscrew to prevent the user from accidentally over cranking the gearbox and having the stainless steel fall out of the lower pole.

Figure 26 Extrusion Tube, Square 1.48 x 1.48 Tube, SS

Guide, Leadscrew / Stainless Steel Guide, PVC:

In addition to the guide which hugs the outside surface of the stainless steel tubing, it was necessary to design an additional guide to make up for the spacing created between the inside of the stainless steel tubing and the leadscrew. Initially, the product was designed without the piece but after some testing it was noticed that there was too much noise being produced when the gearbox was being cranked. After analyzing the issue, it was concluded that a spacer (the piece seen below) was going to be needed in order to reduce the unwanted rattling noise.

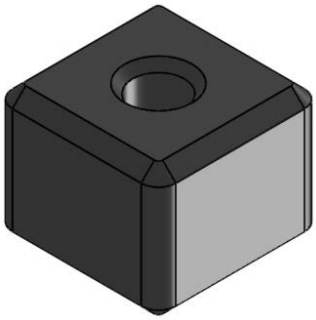


Figure 27 Guide, Leadscrew / Stainless Steel Guide, PVC

Screw Nut, for Stainless Steel Tube, PVC:

In order to convert the rotational energy into translational energy the screw nut was developed. The nut was designed according to the guidelines provided by the manufacturer of the gearbox / leadscrew. For this piece, it was vital to machine a piece with both square and cylindrical features. The cylindrical part of the screw nut serves as a support as it rides inside the tower pole. Its diameter is just a couple of thousandths smaller than the inside diameter of the pole for added efficiency and support. The square top on the piece was needed so that it had a tight fit into the stainless steel tubing, which will then be screwed on using 1/4-20 Button Head Socket Cap Screws so that it will transport the tubing in either the up or down direction.

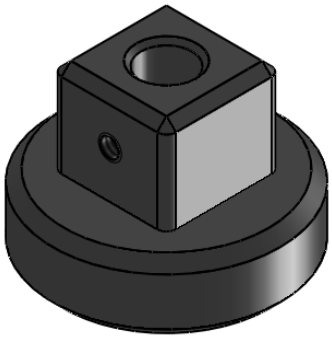


Figure 28 Screw Nut, for Stainless Steel Tube, PVC

Housing, for Gearbox, PVC:

A housing, or spacer, was developed for fitment purposes. Without the development of this part it would not be possible to use the purchased gearbox with the pole. The outside diameter of the gearbox was too small for the inside diameter of the pole causing problems in assembly. The housing, designed to make up the space between the two components proved to be very helpful in the assembly of the system. The part was made of PVC and was machined to be symmetrical so that the same part can be used for the top and bottom of the gearbox.

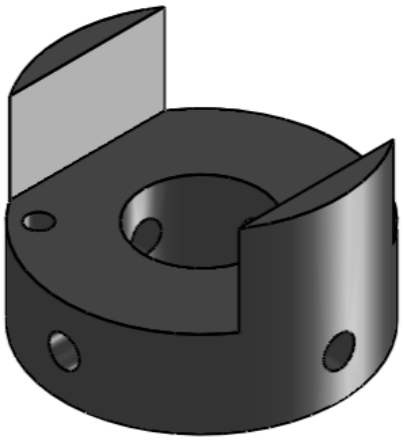


Figure 29 Housing, for Gearbox, PVC

Gearbox and Leadscrew, 4:1 Bevel Gearbox with Leadscrew:

The gearbox and the leadscrew can be considered to be the system's tower heart. The combination of these two components make it possible for energy to be transduced from rotational to linear. The gearbox and leadscrew which was used in the Wind and Hybrid Power System was sourced from a German company called Keterrer Gears. The gearbox chosen (Bevel Gear 4808) has a 1:4 gear ratio, meaning that for every 1 input rotation there are 4 output rotations. This is of advantage as it will would take less time to crank the tower to full extension in a smaller amount of time. According to the manufacturers, the gearbox has max static traction load and max static pressure load of 800 N and 10000 N, respectively.

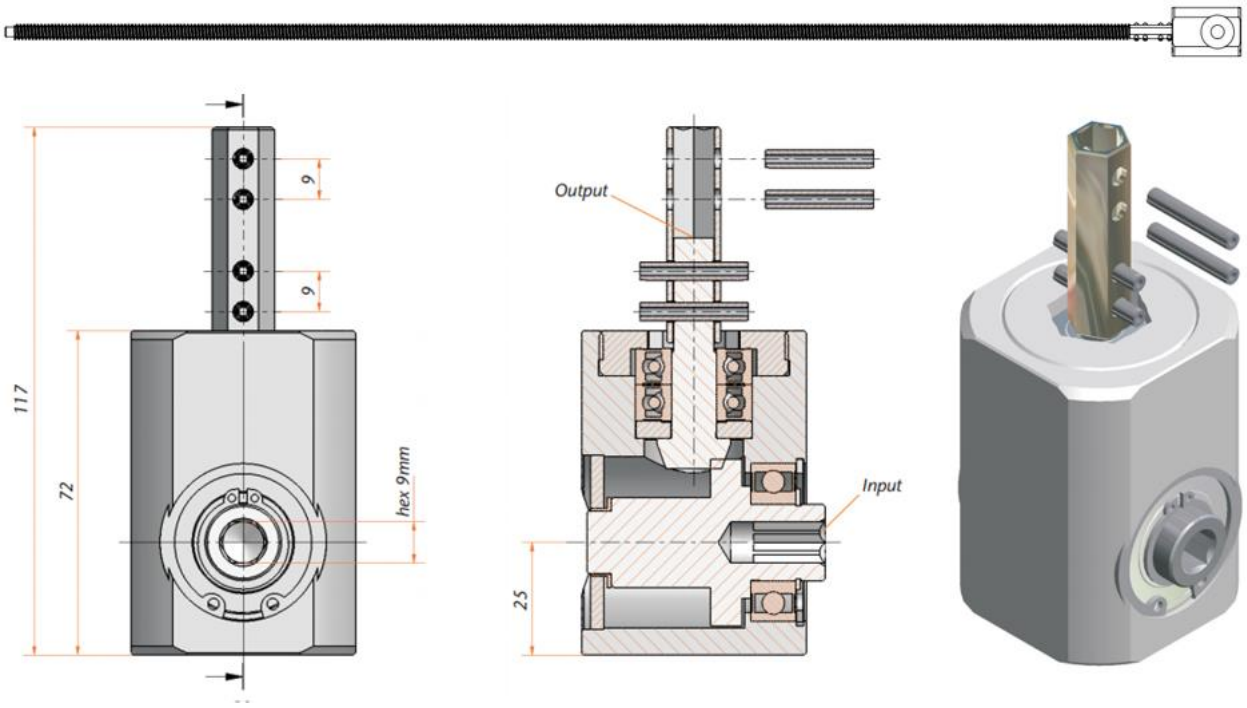


Figure 30 Gearbox and Leadscrew, 4:1 Bevel Gearbox with Leadscrew

5.2 Bill of Materials

When developing and manufacturing a product, it is always critical to have a comprehensive list of raw materials, components and assemblies which were required to build or manufacture a product. Below, one can see a rendering of the Solar and Wind Hybrid Power System. The Bill of Materials which will be listed in this section includes a list of parts that were used in the assembly of the tower (shown in the drawing) and as well as in the electrical power box (not being represented in the drawing).

ITEM #	DESCRIPTION	QTY	UNIT
1001	Tail Boom, Aluminum	1	EACH
1002	Holder, for Tail Boom, Aluminum	1	EACH
1003	Tail Vane, Aluminum	1	EACH
1004	Reinforcement, 1.375 OD x 6" Long Plastic Rod	1	EACH
1005	Reinforcement, 1.375 OD x 14" Long Plastic Rod	1	EACH
1006	Slip Ring	1	EACH
1007	Shaft, PVC Center Pivot Shaft	1	EACH
1008	Bracket, Wind Turbine Pivot Bracket	1	EACH
1009	Stopper, 2" ID x 2.80" OD Ring Stopper for Pivot Bracket	1	EACH
1010	Tower Pole, Top Portion of Tower	1	EACH
1012	Friction Reducing Nylon Ring	1	EACH
1013	Wire Lock, 0.25" x 2.50" Steel Pin with Wire Lock, SS	1	EACH
1014	Guide, Stainless Steel Tube Guide - 7", PVC	1	EACH

1015	Guide, Stainless Steel Tube Guide - 5", PVC	1	EACH
1016	Hub Plate, Blade to Turbine Adapter, SS	1	EACH
1017	Generator, Freedom PMG 12V	1	EACH
1018	Hub Spacer, for Blade to Turbine Adapter, SS	1	EACH
1019	Tower Pole, Bottom Portion of Tower	1	EACH
1020	Extension Tube, Square 1.48 x 1.48 Tube, SS	1	EACH
1021	Guide, Leadscrew / Stainless Steel Guide, PVC	1	EACH
1022	Gearbox and Leadscrew, 4:1 Bevel Gearbox with Leadscrew	1	EACH
1023	Screw Nut, for Stainless Steel Tube, PVC	1	EACH
1024	Housing, for Gearbox, PVC	2	EACH
1025	Blades, Raptor Generation 5 series	5	EACH
1026	Solar Panel, Renogy 100 Watt Solar Panel	1	EACH
1027	Mount, Solar Panel Mount	1	EACH
1028	Battery, EverStart 27DC 109 Amp Marine Battery	2	EACH
1029	Inverter, 1500 Watt Power Inverter	1	EACH
1030	Controller, Ten-high 800w Wind Solar Hybrid Controller	1	EACH
1031	Electrical Box, Blue Hawk 30.5" Wheeled Plastic Tool Box	1	EACH
1032	Hanlde, Gearbos Crank Handle	1	EACH
3001	Screw, 10-32 x 0.5" Button Head Socket Cap Screw, SS	3	EACH
3002	Screw, 1/4-20 x .875" Flat Head Socket Cap Screw, SS	6	EACH
3003	Split Pin, 0.25" x 0.75" Long, SS	4	EACH
3004	Screw, 1/2-13 x 0.75" Round Head Slotted Machine Screw, SS	4	EACH
3005	Nut, 1/2-13 Hex Nut, SS	4	EACH
3006	U Bolt, 3/8 in. x 3-1/16 in. x 4-3/16 in, Zinc Plated	2	EACH
3007	Screw, 5/16-18 x 0.50" Flat Head Socket Cap Screw, SS	4	EACH
3008	Screw, 1/4-20 x .625" Flat Head Socket Cap Screw, SS	2	EACH
3009	Screw, 1/4-20 x 1.50" Flat Head Socket Cap Screw, SS	1	EACH
3010	Screw, 1/4-20 x 0.375" Button Head Socket Cap Screw, SS	2	EACH
3011	Sscrew, 1/4-20 x 0.25" Flat Head Socket Cap Screw, SS	4	EACH
3012	Split Pin, 0.1895" x 1.50" Long, SS	2	EACH
3013	Nut, 3/8-16 Hex Nut, SS	1	EACH
3014	Scew, 14-20 x 0.75" Hex Head Cap Screw, SS	10	EACH
3015	Nut, 1/4-20 Lock Nut, SS	10	EACH
3016	Washer, 3/4" Lock Washer, SS	1	EACH
3017	Nut, 3/4-20 Hex Nut, SS	1	EACH
3018	Screw, 3/8-16 x 4" Hex Head Cap Screw	4	EACH
5001	10 AWG Silicone Wire 10 Feet	1	EACH
5002	Red Marine Battery Cable and Lug Assembly 2 AWG, 24 in	1	EACH
5003	Black Marine Battery Cable and Lug Assembly 2 AWG, 24 in	1	EACH
5004	Red Marine Battery Cable and Lug Assembly 2 AWG, 12 in	1	EACH
5005	Black Marine Battery Cable and Lug Assembly 2 AWG, 12 in	1	EACH
5006	1000 volt PV Wire 10 AWG, 50 feet	1	EACH
5007	RENOGY MC4 Male/Female Connectors (5 Pair Pack)	2	EACH

5008	5/16" Ring Terminals Pack 10-12 AWG	2	EACH
5009	3-phase wire 12 AWG, 25 feet	2	EACH
5010	Cord Grip, for 3 Phase Cable	1	EACH

Table 7 Bill of Materials

As visible from the table above, the complete hybrid power system consists of a total of 59 unique parts, from which 18 of those unique parts were fasteners, 10 were electrical cables/hardware and the 31 were main system components (generator, solar panel, blades, tower, etc.). When individual components come into play, the system is composed of a total of 115 individual parts.

The development of this table has been key in staying organized and keeping track of the expenses which have been incurred in the development and manufacturing of the Solar and Wind Hybrid Power System.

Testing and Evaluation

6.1 Wind Turbine Efficiency

Wind turbines works by converting kinetic energy in the wind first into mechanical power and then a generator converts this mechanical power into electricity. When designing any wind turbine system it is important to know the expected power and energy output of the turbine. In this section of the report we will provide a mathematical model that works for any wind turbine system.

Mathematical Model

The following table shows the definitions of the variables used in this model [10].

E = kinetic Energy (J)	*A* = Swept Area (m^2)
m = Mass (Kg)	*Cp* = Power Coefficient
V = Wind Speed (m/s)	*r* = Radius (m)
P = Power (W)	*x* = distance (m)
ρ = Density (kg/m^3)	*t* = Time (s)

The following equation (1) represents the total energy available in the wind [10].

$$P = \frac{1}{2}\rho A V^3 \quad (1)$$

In 1919 a German physicist Albert Betz concluded that is not possible for a wind turbine to convert more the 59.3% of the kinetic energy available in the wind into mechanical energy by

turning a rotor. This is known as the **Betz Limit** and is the theoretical maximum power efficiency of any wind turbine. This is called the maximum coefficient of power and is defined as [10]:

$$C_{P\max} = 0.59$$

Hence, the power coefficient must be included in equation (1) and the new power extracted from the wind in any wind turbine is given by [1]:

$$P_{\text{avail}} = \frac{1}{2}\rho A V^3 \, C_P \tag{2}$$

where the swept area of the turbine *A* can be calculated using the equation for the area of the circle [10]:

$$A = \pi r^2 \tag{3}$$

where the radius represent the blade length which is shown in the figure bellow:

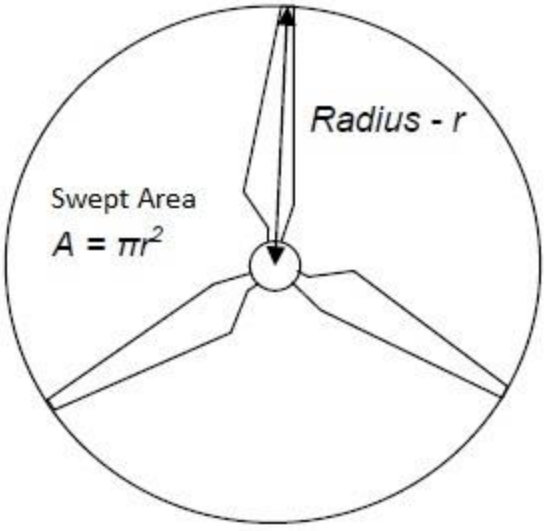


Figure 31 Blade Swept Area [10]

The reasoning behind this efficiency limit is that for a wind turbine to be 100% efficient it would to stop 100% of the wind -- but then for a turbine to collect 100% of the wind the swap area of the wind turbine would have to be a solid disk and it would not turn and no kinetic energy would be converted [2].In other words, for a wind turbine to spin some energy from the wind must scape when passing through the blades and this loss of energy is what "creates" this **Betz Limit**. However, in the real world application even the best wind turbines will have a coefficient of power well the **Betz Limit** with values of 0.35-0.45 [10].

The good thing about having this limit is that it allows designers to obtain a quick estimate of how much power you should expect from a wind generator. For example, assuming a power coefficient of 0.4 we could get a quick estimate of how much power we should be producing at 12mph wind on this design.

Calculations the Following Data

Blade length, *l* = 0.762 m (This is the actual length used on this deign)
Assumed wind speed, *V* = *12* m/sec
Assumed power Coefficient, C_P= 0.4
Air density, ρ = 0.4

Inserting the value for the blade length into equation (3) we get:

$$l = r = 0.762\text{m}$$
$$A = \pi r^2$$
$$= \pi \times 0.762^2$$
$$= 1.824\text{m}^2$$

Now we can calculate the power output of the turbine using equations (2):

$$P_{\text{avail}} = \frac{1}{2}\rho A V^3 \, C_P$$

$= 0.5 \times 1.23 \times 1.824 \times 12^3 \times 0.4$

$= 775$ W

In the calculation above, we assumed that our wind turbine have a power coefficient of 0.4, but that are different ways of actually calculating this value. Some methods rely on the use of what is called the tip speed ratio, however, in order to calculate this ratio it is required to know the rotational speed (RPM) of the turbine which can difficult to obtain. Another method for finding the power coefficient is by comparing the theoretical energy available in the wind with the actual power produced the turbine. Using this method, the coefficient of power is given by [11].

$$C_P = \frac{Actual\ power\ produced\ by\ the\ turbine}{Theoretical\ energy\ available\ in\ the\ wind} \quad (4)$$

Since we already tested our turbine and we have these "actual values" this method is applicable.

Note: The power output of our wind turbine was collected, in a safe and controlled experiment, using an Airboat (on ground) as a source of wind. With the help of a wattmeter, it was possible to determine the power output at different wind speeds. The data for this experiment can be found in the appendix of this report.

The following figure, represents theoretical power output of our system, which was calculated using equation (1), and the actual power output as function of wind speed.

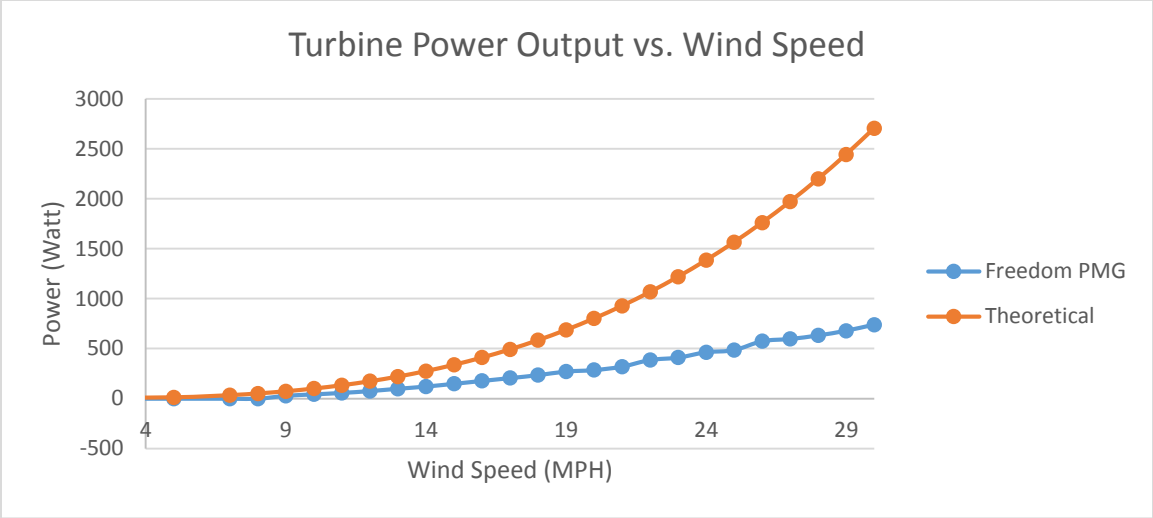


Figure 32 Power Output

The following figure, represents the coefficient of power of our system, which was calculated using equation (4), as function of wind speed.

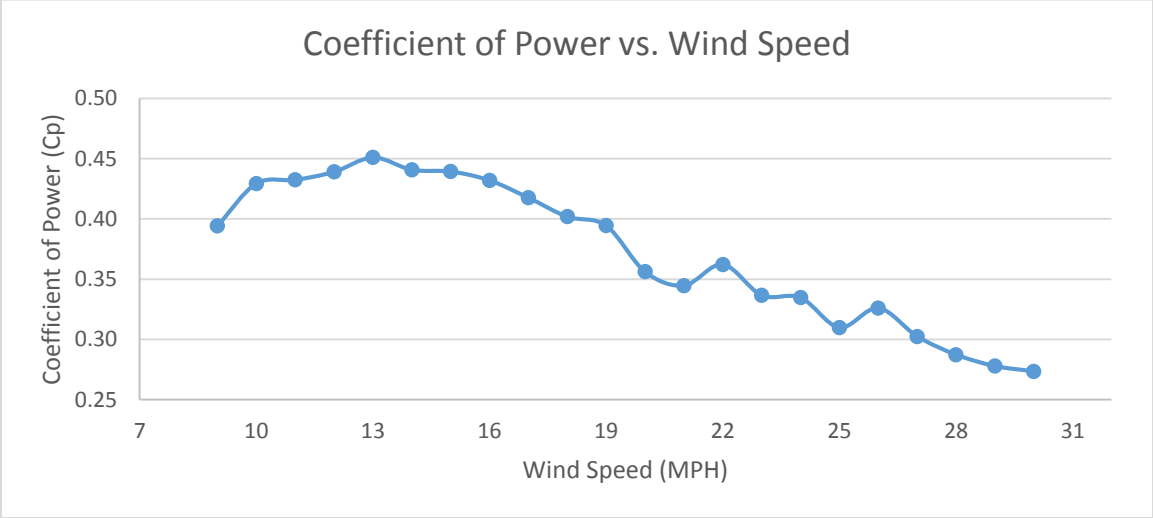


Figure 33 Coefficient of Power

The following figure, represent the efficiency of our winds turbine at different wind speeds. The efficiency was calculated by multiplying the coefficient of power (x 100).

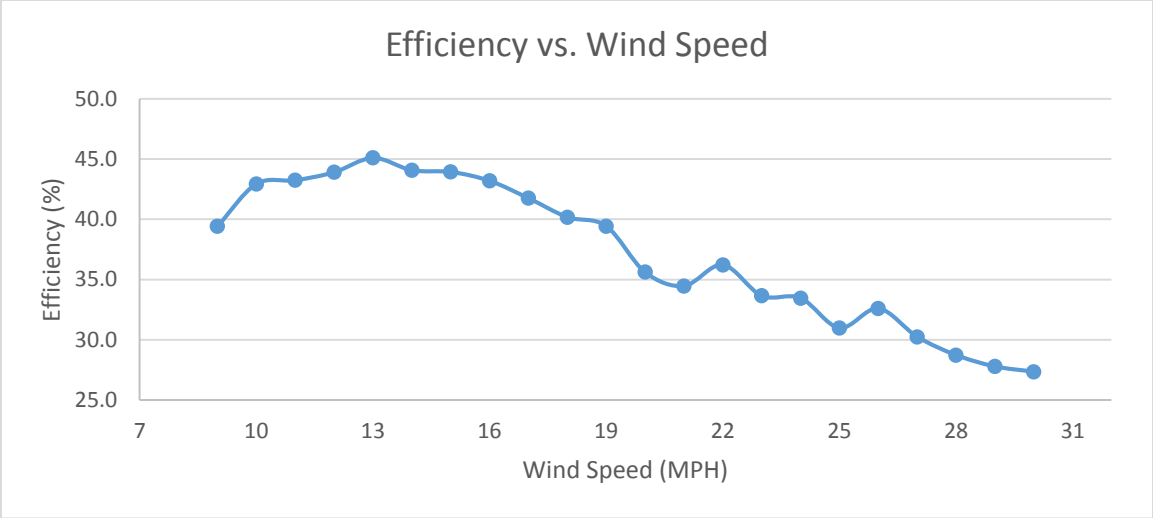


Figure 34 Turbine Efficiency

According to the figure above, our turbine is more efficient at proximally 13 MPH wind. It is important to understand that this 13 MPH only means that at this point the turbine is doing a better job in converting the kinetic energy in the wind into mechanical power, however, at higher wind speeds the turbine will still deliver more power, but just not as efficient as the 13 MPH mark.

6.2 Solar Panel Efficiency

Since we are designing a system that combines both a wind turbine and a photovoltaic sola panel it is import to determine the efficiency of our solar panel. The efficiency in a photovoltaic solar panel measures the ability of the panel to convert sunlight into usable energy [12] and it is fairly easy to calculate.

<u>Mathematical Model</u>

The following table shows the definitions of the variables used to calculate the efficiency of any solar panel [3]:

η = *Efficiency*	E = Incident radiant heat flux (w/m$^{2)}$
P_m= Maximum power output (W)	A_c = Area of collector (m^2)

The maximum efficiency of a photovoltaic solar panel is given by [12]:

$$\eta = \frac{P_m}{E\ x\ A_C} \tag{4}$$

In order to perform this calculation it is safe to assume an incident radiation flux of 1000 W/m^2. Since we know that our solar panel is rated at a maximum power of 100 W and that the area of the collector is approximately 0.6 m^2 we get:

$$\eta = \frac{P_m}{E\ x\ A_C}$$

= 100/(1000 x 0.6)

= 0.17 or 17 %

Considering that most solar panels are 11-20 % efficient [13] this panel is considered very efficient. This value only represents the maximum efficiency under ideal conditions, however, is important to consider that the actual efficiency will depend on other factors, such as the panel orientation, panel pitch, temperature and shade [13].

6.3 Simulations

On this system we will perform a stress analysis at the tip of the tower where blades are located. At high wind speeds, the tower will suffer a considerably high drag force at the blades and for this reason it is always a good idea to use a finite element approach to determine if the system will handle the load. For this analysis we will neglect the drag force on the shaft since its round shape will diverge most of the force.

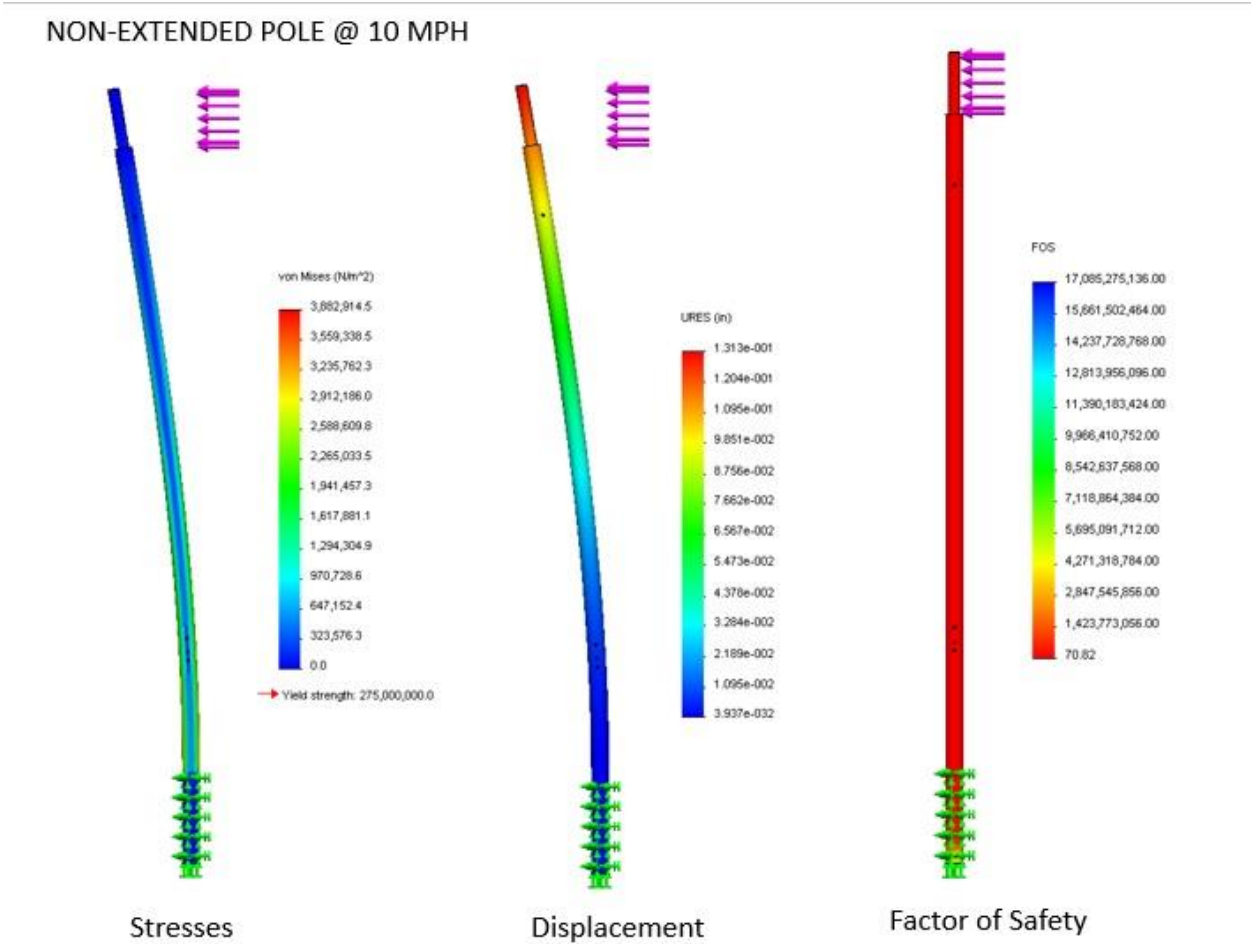


Figure 35 Simulation (10 MPH)

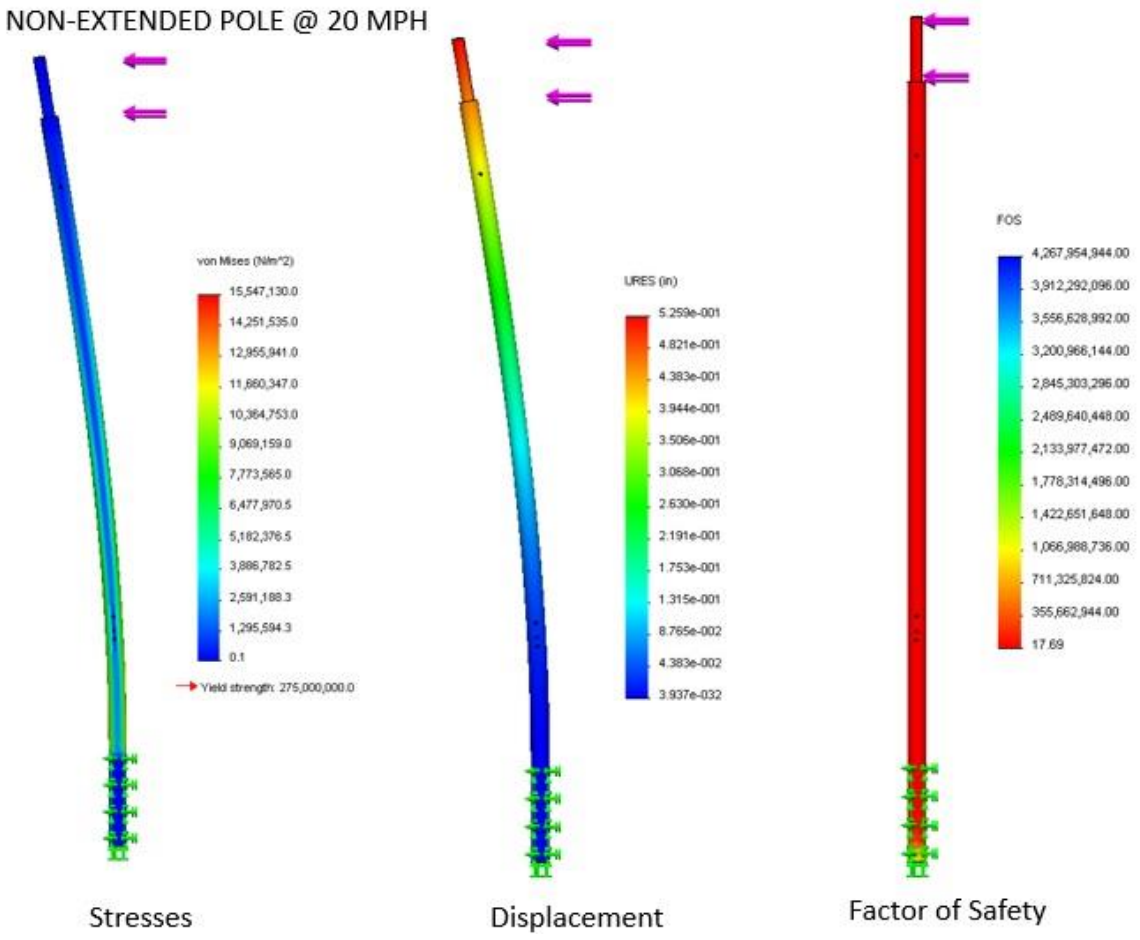
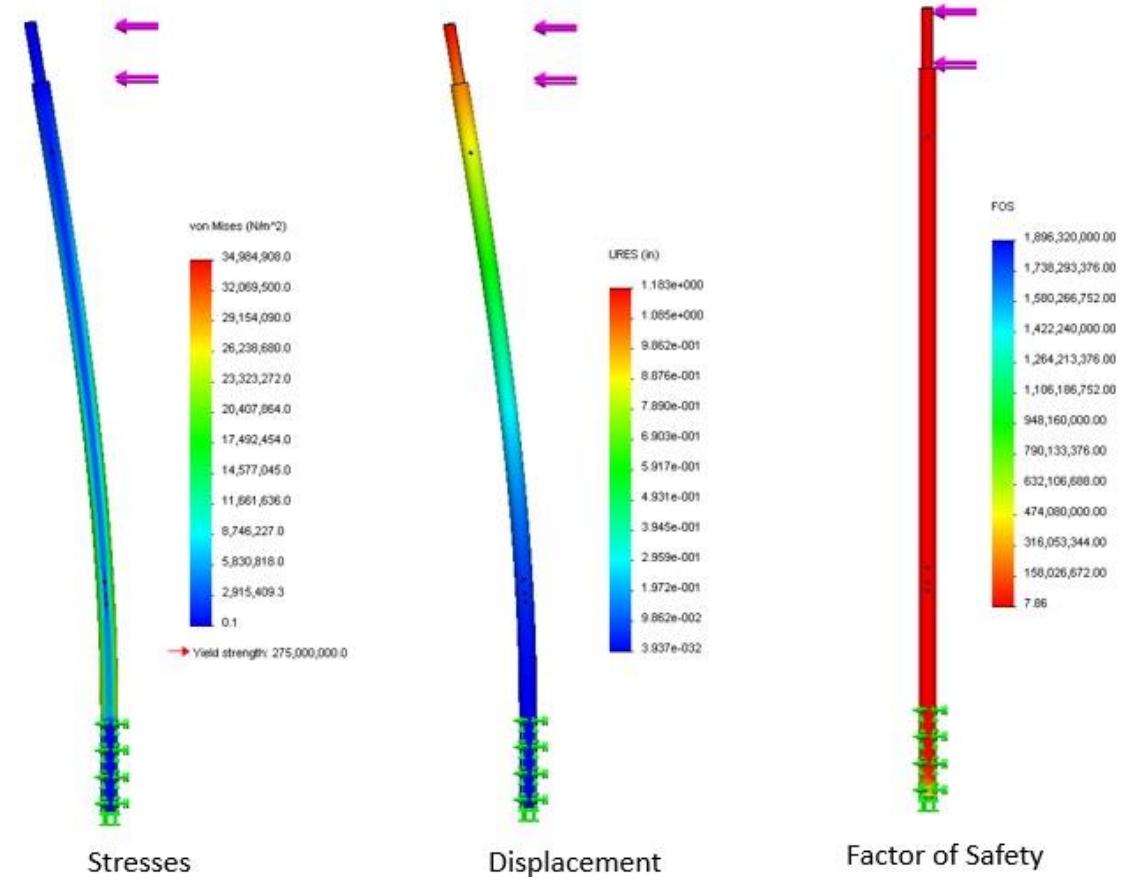


Figure 36 Simulation (20 MPH)

NON-EXTENDED POLE @ 30 MPH



Stresses Displacement Factor of Safety

Figure 37 Simulation (30 MPH)

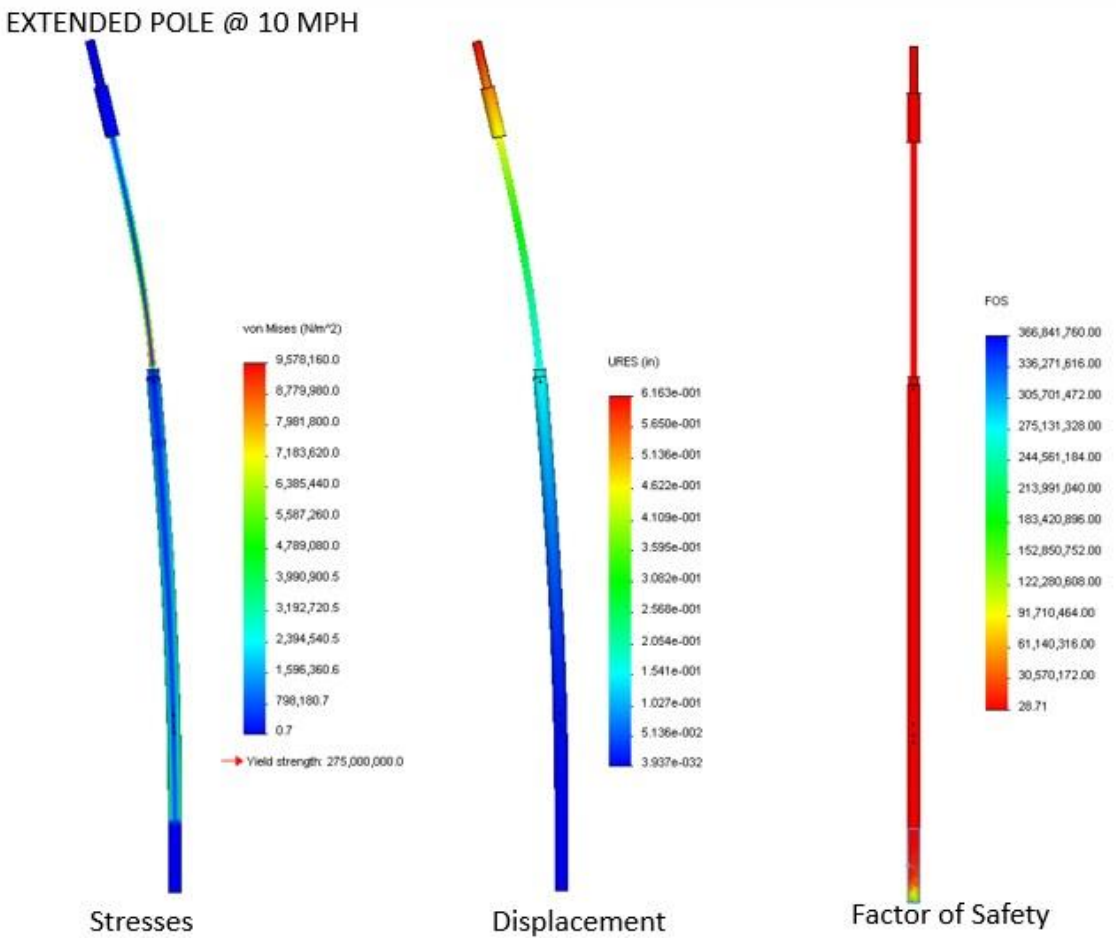


Figure 38 Simulation Extended (10 MPH)

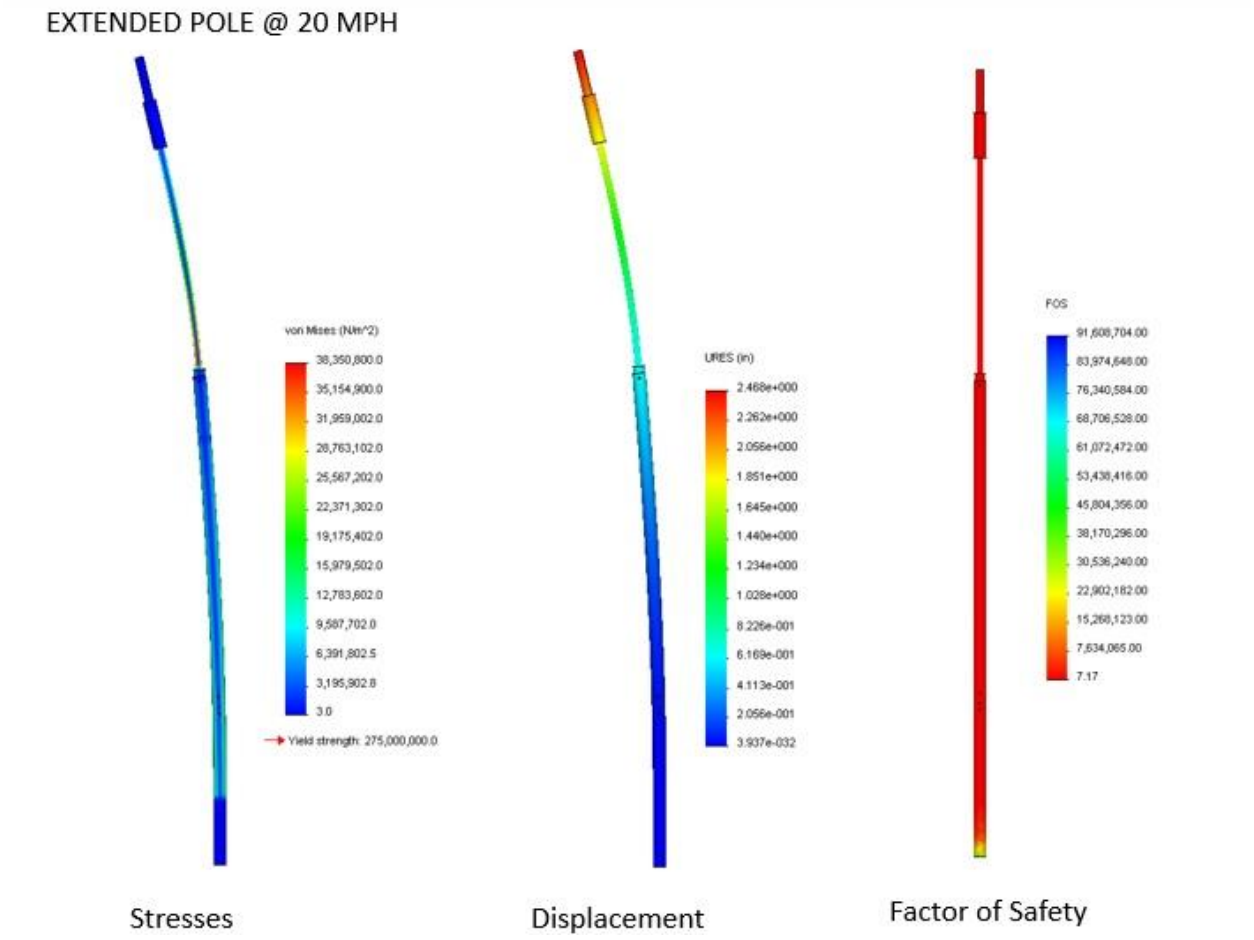


Figure 39 Simulation Extended (20 MPH)

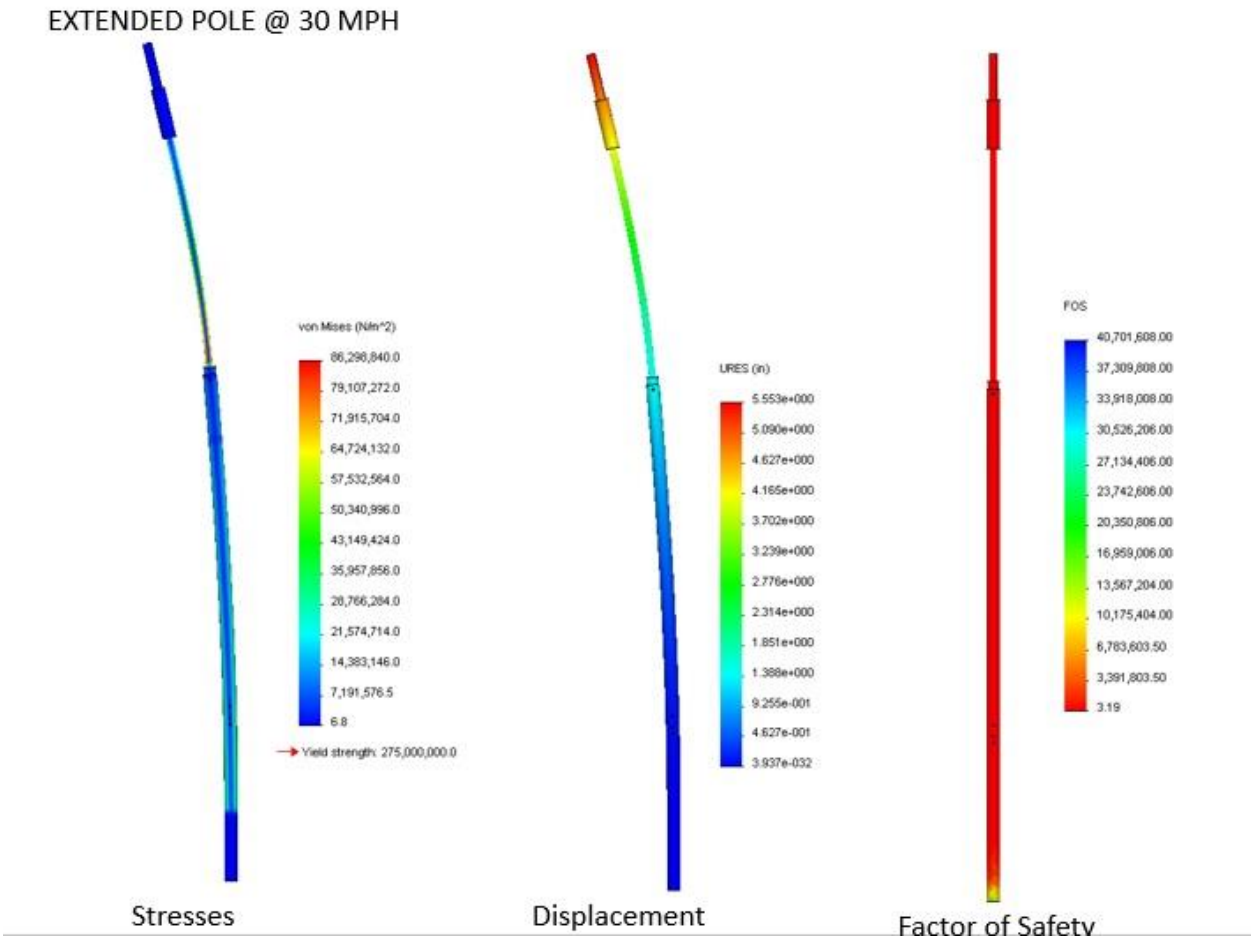


Figure 40 Simulation Extended (30 MPH)

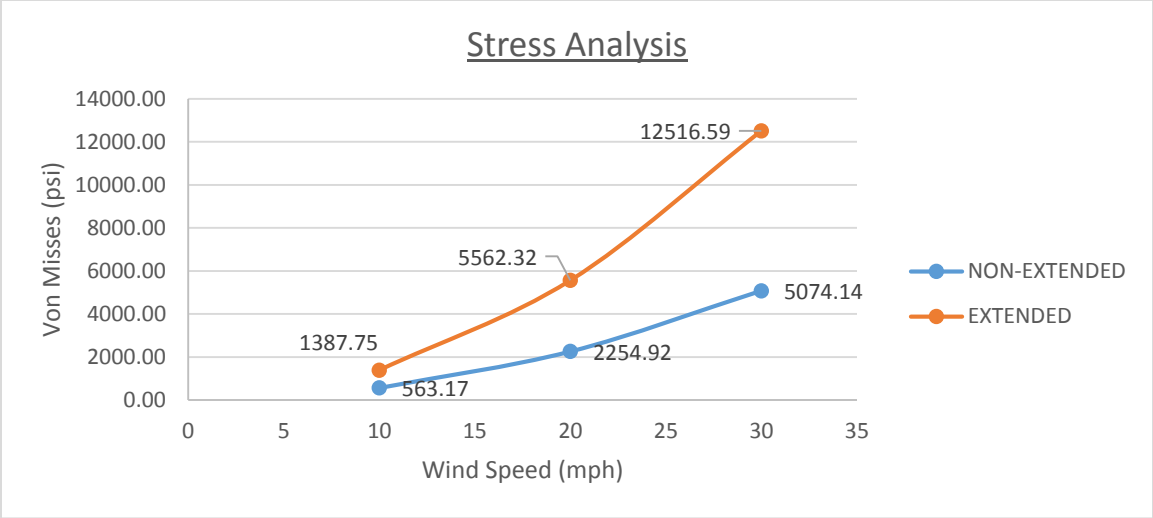


Figure 41 Stress Analysis

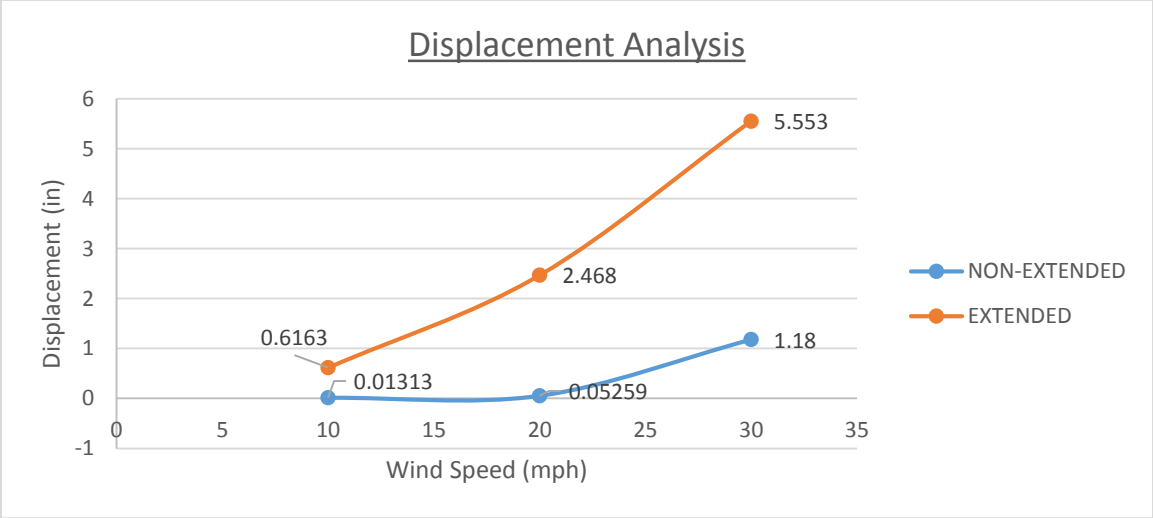


Figure 42 Displacement Analysis

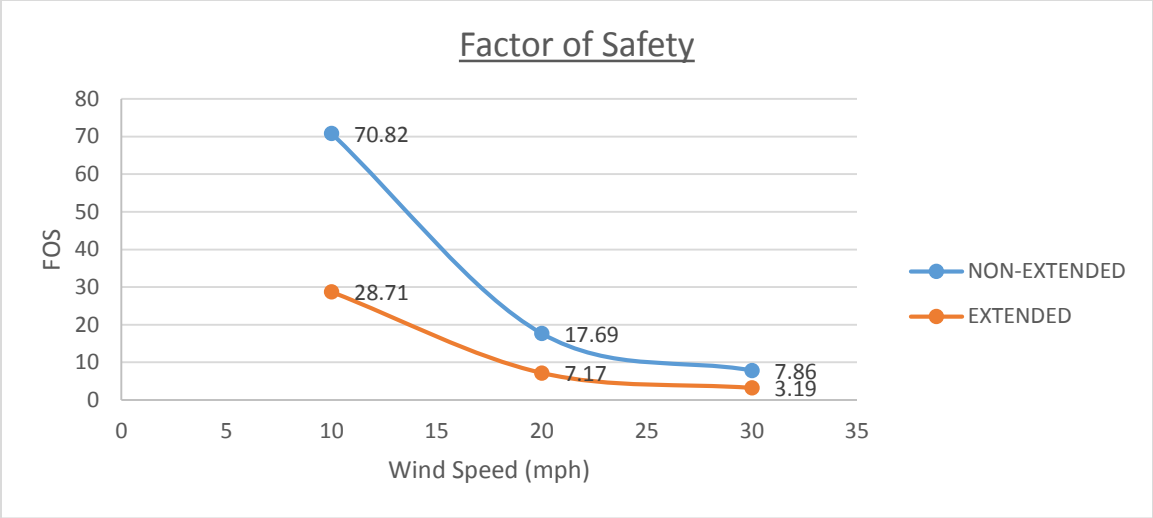


Figure 43 Factor of Safety

Design Considerations

7.1 Cost Breakdown

Cost breakdown, essentially, is the process of identifying individual components that comprise the total cost of a product. Component cost was one of the key focus in designing and building the Solar and Wind Hybrid Power System as the one of the main goals of this project was to develop a superior product at a competitive price.

Note: The cost estimate for the designed power system was calculated using the basic approach of unit costs for bill of quantities. The total was then calculated by summing up the products of the quantities multiplied by the corresponding unit cost. Figures 32 33 and 34 depicts the detailed cost breakdown of the designed Wind and Solar Hybrid Power System.

WIND AND SOLAR HYBRID POWER SYSTEM - FASTENERS						
ITEM #	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT COST**	**TOTAL COST**	**SOURCE**
3001	Screw, 10-32 x 0.5" Button Head Socket Cap Screw, SS	3	EACH	$ 0.07	$ 0.21	McMaster: 92949A265
3002	Screw, 1/4-20 x .875" Flat Head Socket Cap Screw, SS	6	EACH	$ 0.20	$ 1.20	McMaster: 92210A541
3003	Split Pin, 0.25" x 0.75" Long, SS	4	EACH	$ 0.22	$ 0.88	McMaster: 92373A365
3004	Screw, 1/2-13 x 0.75" Round Head Slotted Machine Screw, SS	4	EACH	$ 1.35	$ 5.40	McMaster: 91783A710
3005	Nut, 1/2-13 Hex Nut, SS	4	EACH	$ 1.10	$ 4.40	McMaster: 91851A640
3006	U Bolt, 3/8 in. x 3-1/16 in. x 4-3/16 in, Zinc Plated	2	EACH	$ 2.58	$ 5.16	The Home Depot
3007	Screw, 5/16-18 x 0.50" Flat Head Socket Cap Screw, SS	4	EACH	$ 0.28	$ 1.12	McMaster: 92210A581
3008	Screw, 1/4-20 x .625" Flat Head Socket Cap Screw, SS	2	EACH	$ 0.41	$ 0.82	McMaster: 90585A358
3009	Screw, 1/4-20 x 1.50" Flat Head Socket Cap Screw, SS	1	EACH	$ 0.63	$ 0.63	McMaster: 90585A546
3010	Screw, 1/4-20 x 0.375" Button Head Socket Cap Screw, SS	2	EACH	$ 0.09	$ 0.18	McMaster: 92949A535
3011	Sscrew, 1/4-20 x 0.25" Flat Head Socket Cap Screw, SS	4	EACH	$ 0.18	$ 0.72	McMaster: 92210A297
3012	Split Pin, 0.1895" x 1.50" Long, SS	2	EACH	$ 0.36	$ 0.72	McMaster: 92373A261
3013	Nut, 3/8-16 Hex Nut, SS	1	EACH	$ 0.21	$ 0.21	McMaster: 91841A035
3014	Scew, 14-20 x 0.75" Hex Head Cap Screw, SS	10	EACH	$ 0.11	$ 1.10	McMaster: 92240A540
3015	Nut, 1/4-20 Lock Nut, SS	10	EACH	$ 0.09	$ 0.90	McMaster: 91831A029
3016	Washer, 3/4" Lock Washer, SS	1	EACH	$ 1.00	$ 1.00	McMaster: 98437A140
3017	Nut, 3/4-20 Hex Nut, SS	1	EACH	$ 1.94	$ 1.94	McMaster: 95621A800
3018	Screw, 3/8-16 x 4" Hex Head Cap Screw	4	EACH	$ 4.10	$ 16.40	McMaster: 92198A640
				TOTAL COST OF FASTENERS	**$ 42.99**	

Table 8 Fasteners (Cost)

WIND AND SOLAR HYBRID POWER SYSTEM - ELECTRICAL CABLES / HARDWARE						
ITEM #	DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL COST	SOURCE
5001	10 AWG Silicone Wire 10 Feet	1	EACH	$ 14.99	$ 14.99	Amazon
5002	Red Marine Battery Cable and Lug Assembly 2 AWG, 24 in	1	EACH	$ 14.44	$ 14.44	Amazon
5003	Black Marine Battery Cable and Lug Assembly 2 AWG, 24 in	1	EACH	$ 14.44	$ 14.44	Amazon
5004	Red Marine Battery Cable and Lug Assembly 2 AWG, 12 in	1	EACH	$ 8.00	$ 8.00	Amazon
5005	Black Marine Battery Cable and Lug Assembly 2 AWG, 12 in	1	EACH	$ 8.00	$ 8.00	Amazon
5006	1000 volt PV Wire 10 AWG, 50 feet	1	EACH	$ 32.68	$ 32.68	Amazon
5007	RENOGY MC4 Male/Female Connectors (5 Pair Pack)	2	EACH	$ 9.99	$ 19.98	Amazon
5008	5/16" Ring Terminals Pack 10-12 AWG	2	EACH	$ 2.99	$ 5.98	AutoZone
5009	3-phase wire 12 AWG, 25 feet	2	EACH	$ 32.25	$ 64.50	Missouri Wind and Solar
5010	Cord Grip, for 3 Phase Cable	1	EACH	$ 4.43	$ 4.43	McMaster: 69915K55
				TOTAL COST OF ELECTRICAL CABLES / HARDWARE	$ 187.44	

Table 9 Hardware (Cost)

WIND AND SOLAR HYBRID POWER SYSTEM - COMPONENTS						
ITEM #	DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL COST	COMMENTS / SOURCE
1001	Tail Boom, Aluminum	1	EACH	$ 15.00	$ 15.00	Eastern Metal: 17-63-116
1002	Holder, for Tail Boom, Aluminum	1	EACH	$ 35.00	$ 35.00	Southern Manufacturing
1003	Tail Vane, Aluminum	1	EACH	$ 15.00	$ 15.00	Southern Manufacturing
1004	Reinforcement, 1.375 OD x 6" Long Plastic Rod	1	EACH	$ 6.00	$ 6.00	TUUCI Machine Shop
1005	Reinforcement, 1.375 OD x 14" Long Plastic Rod	1	EACH	$ 6.00	$ 6.00	TUUCI Machine Shop
1006	Slip Ring	1	EACH	$ 25.99	$ 25.99	Techex Online
1007	Shaft, PVC Center Pivot Shaft	1	EACH	$ 30.00	$ 30.00	TUUCI Machine Shop
1008	Bracket, Wind Turbine Pivot Bracket	1	EACH	$ 49.95	$ 49.95	Missouri Wind and Solar
1009	Stopper, 2" ID x 2.80" OD Ring Stopper for Pivot Bracket	1	EACH	$ 15.00	$ 15.00	TUUCI Machine Shop
1010	Tower Pole, Top Portion of Tower	1	EACH	$ 7.00	$ 7.00	Eastern Metal: 18-63-245
1012	Friction Reducing Nylon Ring	1	EACH	$ 3.00	$ 3.00	M.R. Machine Shop, Inc
1013	Wire Lock, 0.25" x 2.50" Steel Pin with Wire Lock, SS	1	EACH	$ 6.96	$ 6.96	McMaster: 98480A013
1014	Guide, Stainless Steel Tube Guide - 7", PVC	1	EACH	$ 15.00	$ 15.00	TUUCI Machine Shop
1015	Guide, Stainless Steel Tube Guide - 5", PVC	1	EACH	$ 15.00	$ 15.00	TUUCI Machine Shop
1016	Hub Plate, Blade to Turbine Adapter, SS	1	EACH	$ -	$ -	Came with Blades
1017	Generator, Freedom PMG 12V	1	EACH	$ 219.95	$ 219.95	Missouri Wind and Solar
1018	Hub Spacer, for Blade to Turbine Adapter, SS	1	EACH	$ -	$ -	Came with Generator
1019	Tower Pole, Bottom Portion of Tower	1	EACH	$ 65.00	$ 65.00	Eastern Metal: 18-63-245
1020	Extension Tube, Square 1.48 x 1.48 Tube, SS	1	EACH	$ 45.00	$ 45.00	TUUCI Machine Shop
1021	Guide, Leadscrew / Stainless Steel Guide, PVC	1	EACH	$ 5.00	$ 5.00	Southern Manufacturing
1022	Gearbox and Leadscrew, 4:1 Bevel Gearbox with Leadscrew	1	EACH	$ 110.00	$ 110.00	Ketterer Gears
1023	Screw Nut, for Stainless Steel Tube, PVC	1	EACH	$ 15.00	$ 15.00	TUUCI Machine Shop
1024	Housing, for Gearbox, PVC	2	EACH	$ 10.00	$ 20.00	TUUCI Machine Shop
1025	Blades, Raptor Generation 5 series	5	EACH	$ 15.99	$ 79.95	Missouri Wind and Solar
1026	Solar Panel, Renogy 100 Watt Solar Panel	1	EACH	$ 149.99	$ 149.99	Amazon
1027	Mount, Solar Panel Mount	1	EACH	$ 74.99	$ 74.99	Amazon
1028	Battery, EverStart 27DC 109 Amp Marine Battery	2	EACH	$ 81.67	$ 163.34	Walmart
1029	Inverter, 1500 Watt Power Inverter	1	EACH	$ 129.99	$ 129.99	Harbor Freight Tools
1030	Controller, Ten-high 800w Wind Solar Hybrid Controller	1	EACH	$ 139.00	$ 139.00	Amazon
1031	Electrical Box, Blue Hawk 30.5" Wheeled Plastic Tool Box	1	EACH	$ 49.98	$ 49.98	Lowe's
1032	Hanlde, Gearbos Crank Handle	1	EACH	$ 5.00	$ 5.00	TUUCI Machine Shop
				TOTAL COST OF SYSTEM COMPONENTS	$ 1,517.09	

Table 10 Components (Cost)

TOTAL COST OF WIND AND SOLAR HYBRID POWER SYSTEM:		
DESCRIPTION	**COST**	
TOTAL COST OF SYSTEM COMPONENTS	$	1,517.09
TOTAL COST OF FASTENERS	$	42.99
TOTAL COST OF ELECTRICAL CABLES / HARDWARE	$	187.44
TOTAL	**$**	**1,747.52**

Table 11 Total Cost

From the table it is noticed that the most expensive items were the systems main components – generator, solar panel, wind turbine blades, gearbox and batteries. These are costs which are very unlikely to get at lower prices unless they are developed in-house. For this reason, the costing tables above assumes that these parts will always be sourced from the vendors. For all other components, excluding fasteners and electrical cables and hardware, cost is less impactful because the cost for manufacturing the parts in house or purchasing from outside vendors at high volumes has been recorded. These wholesale material and labor costs were attained with the help of a local umbrella manufacturing company, TUUCI, and a local machine shop, Southern Manufacturing.

After analyzing the tables with suppliers and vendors, it is concluded that the final manufacturing cost of the Solar and Wind Hybrid Power System comes out to be approximately $1,747.52. The total cost of the system was broken down into three sub-sections, which consisted of system components ($1,517.09), fasteners ($42.99), and cables / hardware ($187.44). The calculated cost not only includes component and material cost but has also taken into account labor for production of each part that makes up the system. When compared to similar hybrid power systems in the present market, the cost which has been calculated for manufacturing a sophisticated product as the one that has been designed, seems reasonable. Currently, hybrid

power systems with similar specifications are being marketed in the range of $1,500.00 to $2,500.00.

Essentially, what the results of this cost analysis is stating is that the system has been financially optimized. Considering the fact that this is only the first version of the system and that there is still much to be improved in terms of material usage, this system can very well be considered to be a top contender in the market.

7.3 Instruction Manual

Like all technological advance products, it was of utmost importance to develop an instruction manual (also call an owner's manual). The instruction manual which has been created for the Solar and Wind Hybrid Power System contains the following information:

- Assembly Instructions
    - The Solar and Wind Hybrid Power System will be shipped to their destinations in pieces for easier shipping. This is very advantageous is it reduces the risk of the product damaging during transportation and reduces the overall shipping cost of the unit.
- Instructions for use
    - The power system has been designed so that once it has been fully assembled, minor instructions are needed to operate it. Once the system has been completely assembled, the main operations would be to crank the tower to its extended position and plug their electronics into the power jacks on the inverter.

- Safety Instructions
    - For liability reasons, safety instructions have been included in the instruction manual. Within this section, one will find warning against performing that are ill-advised for product longevity and for user safety reasons. Example of ill-advised operations include trying to bring the turbine blades to a stop while in operation and touching the battery terminals inside the power system box.
- Maintenance Instruction
    - Maintenance Instructions are perhaps the most important instructions one has to follow when owning a Power System. For this reason, a section that explains the care and servicing of the system by the user to maintain the system in satisfactory operating conditions has been included.
- Regulatory Code
    - Some cities and areas have certain codes that they need to watch out for. A brief overview of some of these regulations has been written so that the user is aware of problems that may arise if installed in incorrect locations.
- Technical Specifications
    - A technical data sheet describing the technical characteristics of the Hybrid Power System has been also included within the instruction manual booklet so that the user is aware of the systems capacities.

The provided instruction manual comes in multilingual versions (English and Spanish) so that anyone from any nationality has the ability to Assemble, operate and maintenance the system.

Note: The instruction manual of this system can be found in Appendix C.

Design Experience

8.1 Overview

This project has taught us that the process of taking a product from concept to production is not as simple as initially thought. The process of completing this project has developed each of the team member's skills at developing conceptual ideas through market research and consultation with professionals in the fields. Design skills were also further developed by the use of CAD software such as SolidWorks and AutoCAD. In addition, manufacturing skills, such as machining and construction, assembly, material sourcing and costing were also enhanced throughout the completion of the project.

8.2 Standards used in the Project

In the development of this project the following standards were researched and applied:

- NPS – Nominal Pipe Size
- ISO – International Organization for Standardization
- ANSI – American National Standards Institute
- ASME – American Society of Mechanical Engineers
- IEEE – Institute of Electrical and Electronics Engineers

8.3 Global Learning & Design

When designing and manufacturing the Solar and Wind Hybrid Power System it was important to take into account the global learning aspect and global design impact the product was going to have. All the components and materials that are being used in the system are items that are easy available both locally and internationally. What makes this system special is the fact that it has components that come from different parts of the world, such as Germany, Vietnam and China.

In order to have a global impact and footprint, a multi-lingual user's manual and assembly instruction was developed. The instruction manual, which is attached to the appendix section of this report, has been made available in English, Spanish, and Portuguese. We understand the importance of having this product available to people all over the world so in order to better support them further work will be needed to translate instructions to other major languages, such as Mandarin, Hindi, and Arabic.

The Solar and Wind Hybrid Power System was designed so that it can be manufactured anywhere in the world. For this reason manufacturing drawings were completed using both ANSI and ISO drawings standards. Careful attention was taken when assigning tolerances in order to avoid tolerance stack-ups.

Finally, since this is a power system, warning labels have been placed on the product in order to avoid bodily injuries and electrocution. The labels which have been placed on the final design only includes English labels, but we understand that the other languages need to be printed on them depending on the location.

Depending on the demand and amount of investors, we plan to donate one power system per 10 sold to families in developing countries. The impact that this will have around the globe in tremendous, as it will be capable of supplying power to many who cannot afford it. This system is definitely capable of powering up an entire house in the USA but will definitely be capable delivering the necessary electricity to families in developing nations.

8.4 Life-Long Learning Experience

This senior design project paved the way for the road to new learning experiences we will endeavor as engineers in the world. Working as a part of a team to meet deadlines, create designs, cost estimates, network with working professionals in the renewable energy industry, attend meetings, and overall work effectively with one another was learning experience in its own. The Solar and Wind Hybrid System project enabled the team to see the lack of progression that rural communities have in terms of access to electricity. Understanding the problem in a deep cognitive and social level is essential to determine outside the box solutions for rural communities that our senior design project focused on.

In addition in understanding the social impact that our project has had for our team to succeed in future related endeavors, the Solar and Wind Hybrid System also made us experience real life engineering struggles. For example, meeting deadlines and presenting concepts to our peers and professors (clients), educated us in the proper way to prepare ourselves and deliver to the client a product that has been fully evaluated and analyzed critically for the safe and practical use of the consumer. Properly receiving the feedback from our professors in a constructive

manner has definitely refined us as better engineers to handle the stress and pressures of re-evaluating a product to meet the standards of the client.

One of the most important ventures as a team we faced that will definitely have a positive impact in lifelong learning experience cooperatively working together as engineers with different personalities, train of thoughts, cultures, technical experience, and logical reasoning. This let alone, will help us strive in any engineering environment we could be faced with in the future. To able handle the circumstances when team member are not cooperating in a high stress environment and make the effort to correct this for the end product is crucial. Circumstances where employees do not mix well and are mandated to work together exist in everyday life jobs and especially in engineering careers. This senior design project has taught us in a rough manner, to understand each other as individuals and use constructive criticism to enable to grow as better engineer for the future.

Conclusion

9.1 Conclusion

The objective of his project was to design a portable power system that combines both, a wind turbine and a solar panel in one single unit. The main idea of combining the two types of systems together was to try to archive a constant power production, which would be available most of the time. Our hybrid system is capable of producing 1.5 KWh a day. In terms of comparison, during winter a typical 4 person household in America uses an average of 19.5 KWh/day [14], which is approximately 13 times more energy than this portable system is able to produce. However, the purpose of this system was not to power a house or any large system, our main goal was to provide a power solution for remote areas that are not fitted with an electric distribution system. These types of systems are known today as **remote area power supply** (RAPS) which can be very useful in many locations around the globe.

The power output of 1.5 KWh might seem low at a first glance. However, we must consider that a remote area will not use the same number of electrical components as in a "typical modern home" so in many cases this power output can be extremity helpful. In terms of comparison, 1.5 kWh/day is enough to power 3 laptop computers for 10 hours a day or for example, 5 light bulbs for 5 hours a day, or a small hot plate for one hour a day. The capacity to generate this much power can be lifesaving in many situations. Our final product turned out to be a successes and the greatest feature of our design is the portability of the system. All the components can easily be disassembled into small pieces, facilitating transportation, and reassembly just as easily in any location where there is some wind/sun. This process of reassembling the unit is not only fairly

easy, but it also does not require advanced technical knowledge. According to our calculations and testing results, this hybrid system is fully functional, safe and efficient.

The most challenging part of this project was to actual design something new only existed in our imagination. During our research, we found that there is not enough information available to the public about how to create a portable solar & wind hybrid system. There for, as a team, we had to use all the principles that we learned during this major to design and to build something new with a potential to make a difference.

This report can be considered a manual in itself and we certainly answered all the question that we had when designing this system. This means, that any person that studies this document will be able to design exactly the same system and obtains similar or same results. In this report we were able to present the methodology and results of this study which can be used as a reference for future developments and improvement is portable power systems.

9.2 Future Work

The final product which has been developed works as designed. Though much time and work has been invested in designing and developing this product, there is still many other ideas which were not developed because of time constraints. Like is the case with every product development team in the manufacturing world, time is always a problem. Teams wish to have unlimited time to invest on developing a product but it is more important to bring something out to the table early to see how it is perceived by the customers. If things seem unpleasant or if modifications need to be done a second version of the product will be worked on and released.

As a team with many innovative ideas we believe that the implementation of the following ideas will make the designed Solar and Wind Hybrid Power System a better product:

- Design and adapt a lightweight base that is permanently fixed to the tower of the power system.
    - Many portable power systems in the market have been developing their products with built in bases. They are lightweight and are easy to assemble. By implementing a built in base to the design, customers will not have to worry about how they will be setting up their power system.
- Design and manufacture a cover for the permanent magnet wind turbine generator
    - In order to better protect the product and reduce customer complaints in the future, it is always a good idea to take protect the systems key component. By developing a cover for the generator, quality will increase tremendously as it will be protected from rain, snow, and dirt. Throughout time, these types of particles can have a tremendous burden on the system.
- Source and adapt a spring loaded cable retractor.
    - Currently, when the tower is brought from the fully extended position to the non-extended position the cable needs to be pulled so that it does not sag or get jammed in the process. Implementation of a spring loaded cable retractor will improve the overall quality and presentation of the system and as well as improve the overall customers experience by having them be responsible for one less step.
- Investigate a more efficient and visually acceptable way of passing the generator cables through the tower.

- For aesthetic and safety purposes, it is recommended for future teams to enhance the manner of which the generator cables are wired to connect to the electrical box system. For example, finding a thin tube with an ID big enough for the 3 phase cable to pass through and welding it to the side of the tower.

- Implement a safety cover for the turbine blades
  - Safety should always be a priority when designing a product. When the turbine blades begin to rotate they are a danger to humans and avian species as well because of their sharp edges. So, in order to reduce liability and not hurt the environment, it is highly recommended to add a safety cover for the blades.

Although the final design came to life and is working condition, it is still far from perfect. But, by implementing the previously mentioned ideas, it will be well on its way to becoming a top of the line product.

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[4] Renogy 100W 12V Monocrystalline Solar Panel. Digital image. Renogy. N.p., n.d. Web. 1 Mar. 2015. <http://www.renogy-store.com/Renogy-100W-12V-Mono-Solar-Panel-p/rng-100d.htm>.

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[9] Blue Hawk 30.5-in Wheeled Black Plastic Tool Box. Digital image. Lowe's. N.p., n.d. Web. 1 Mar. 2015. <http://www.lowes.com/pd_336429-1156-9124SR_0__?productId=3355634>.

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[14] "Average Household Electricity Usage." *Energy Made Easy*. N.p., n.d. Web. 18 Mar. 2015.

Appendices

Appendix A: Experimental Data

Wind Speed (m/sec)	Wind Speed (MPH)	Current (Amps)	Voltage (Volts)	Power (Watt)
0.0	0	0.00	0.00	0
2.2	5	0.00	0.00	0
3.1	7	0.00	0.00	0
3.6	8	0.00	0.00	0
4.0	9	2.21	13.03	29
4.5	10	3.30	13.04	43
4.9	11	4.40	13.11	58
5.4	12	5.80	13.11	76
5.8	13	7.50	13.24	99
6.3	14	9.10	13.32	121
6.7	15	11.00	13.51	149
7.2	16	13.01	13.63	177
7.6	17	14.92	13.78	206
8.0	18	16.86	13.93	235
8.5	19	19.20	14.12	271
8.9	20	20.08	14.22	286
9.4	21	22.17	14.43	320
9.8	22	26.40	14.64	386
10.3	23	27.69	14.82	410
10.7	24	30.66	15.12	464
11.2	25	32.00	15.16	485
11.6	26	37.28	15.40	574
12.1	27	38.74	15.40	597
12.5	28	40.33	15.67	632
13.0	29	42.84	15.85	679
13.4	30	45.81	16.15	740

Table 12 Experimental Data

Appendix B: Drawings

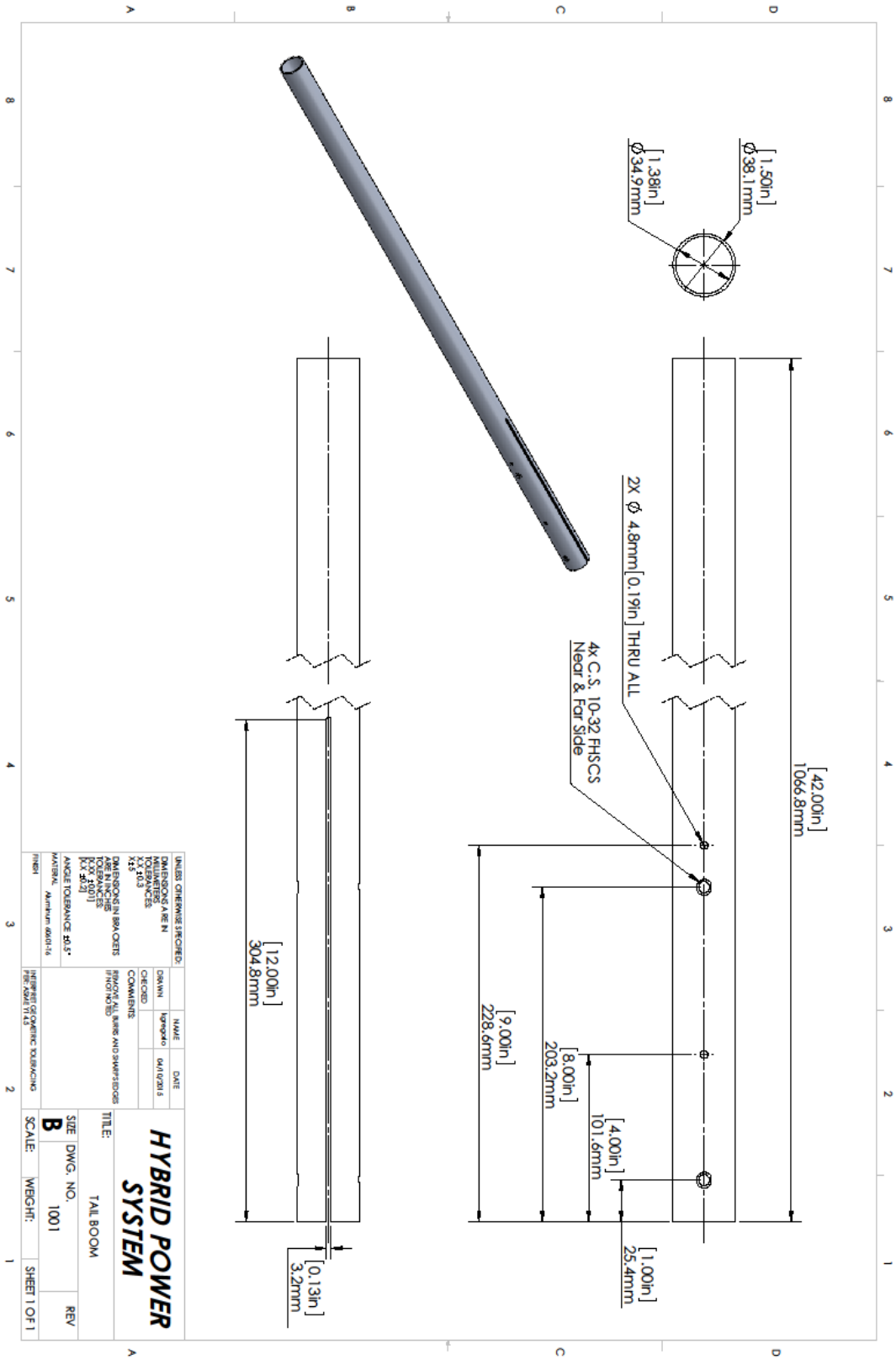


Figure 44 Tail Boom

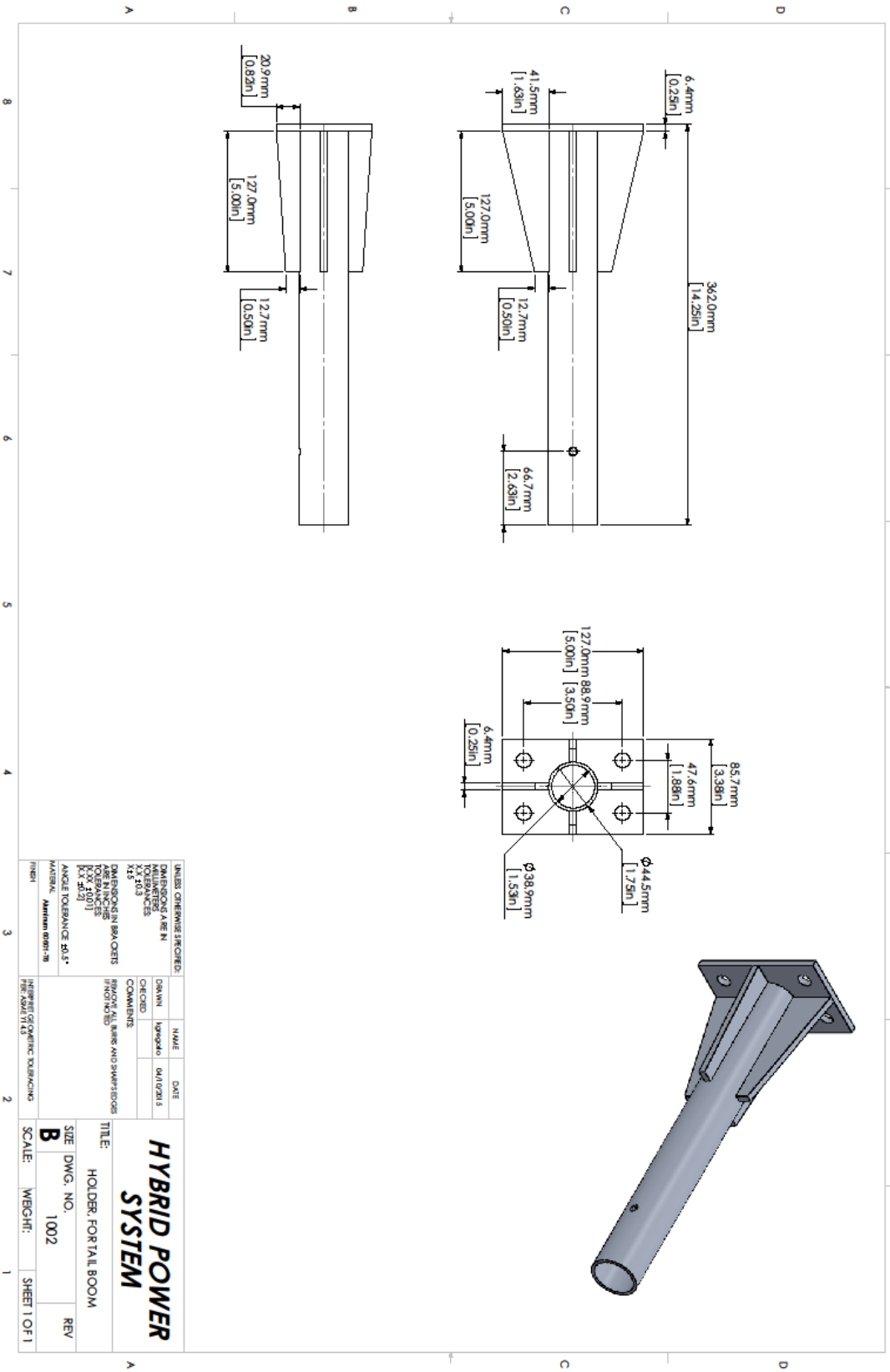


Figure 45 Tail Holder

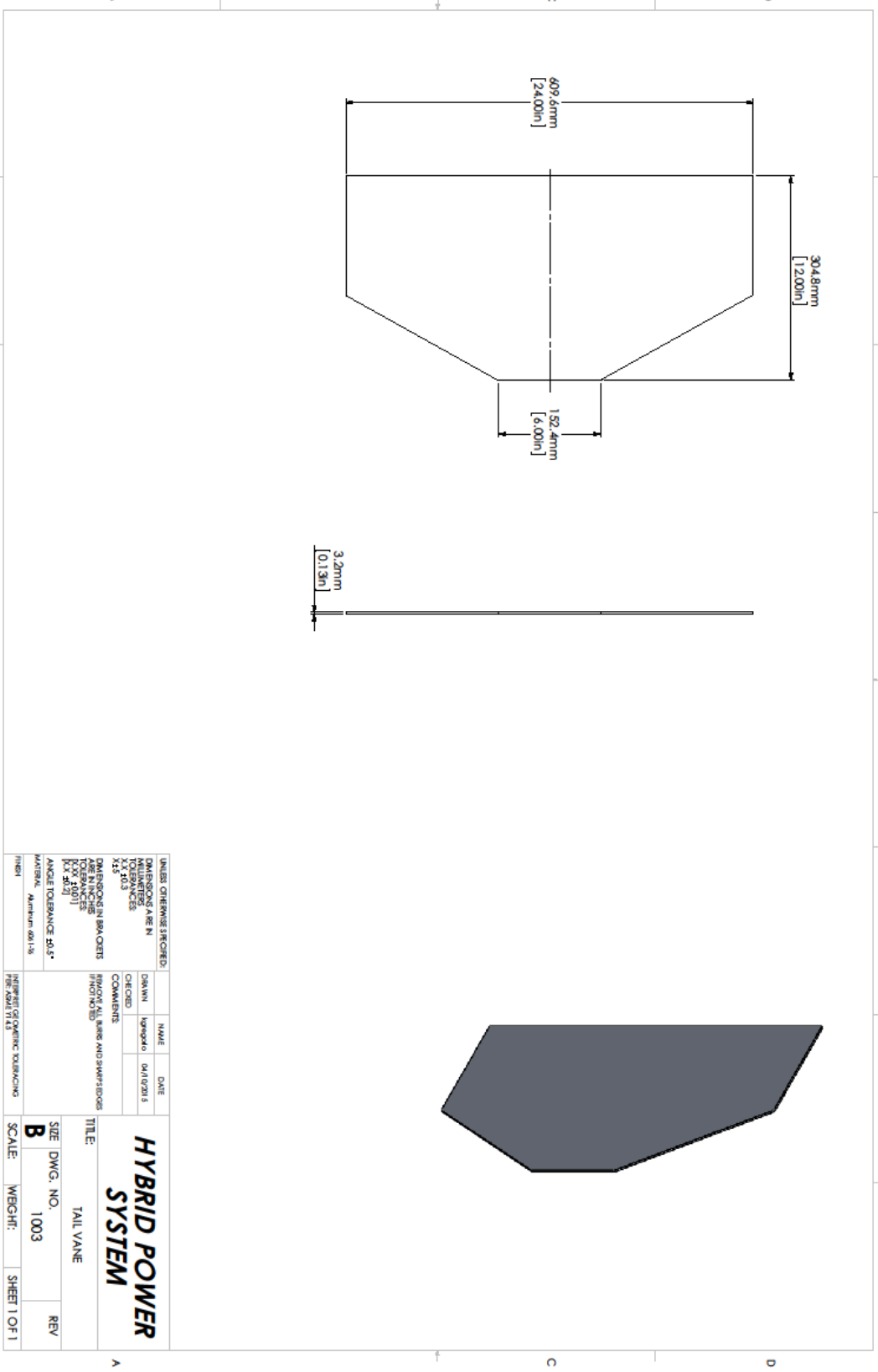


Figure 46 Tail Vane

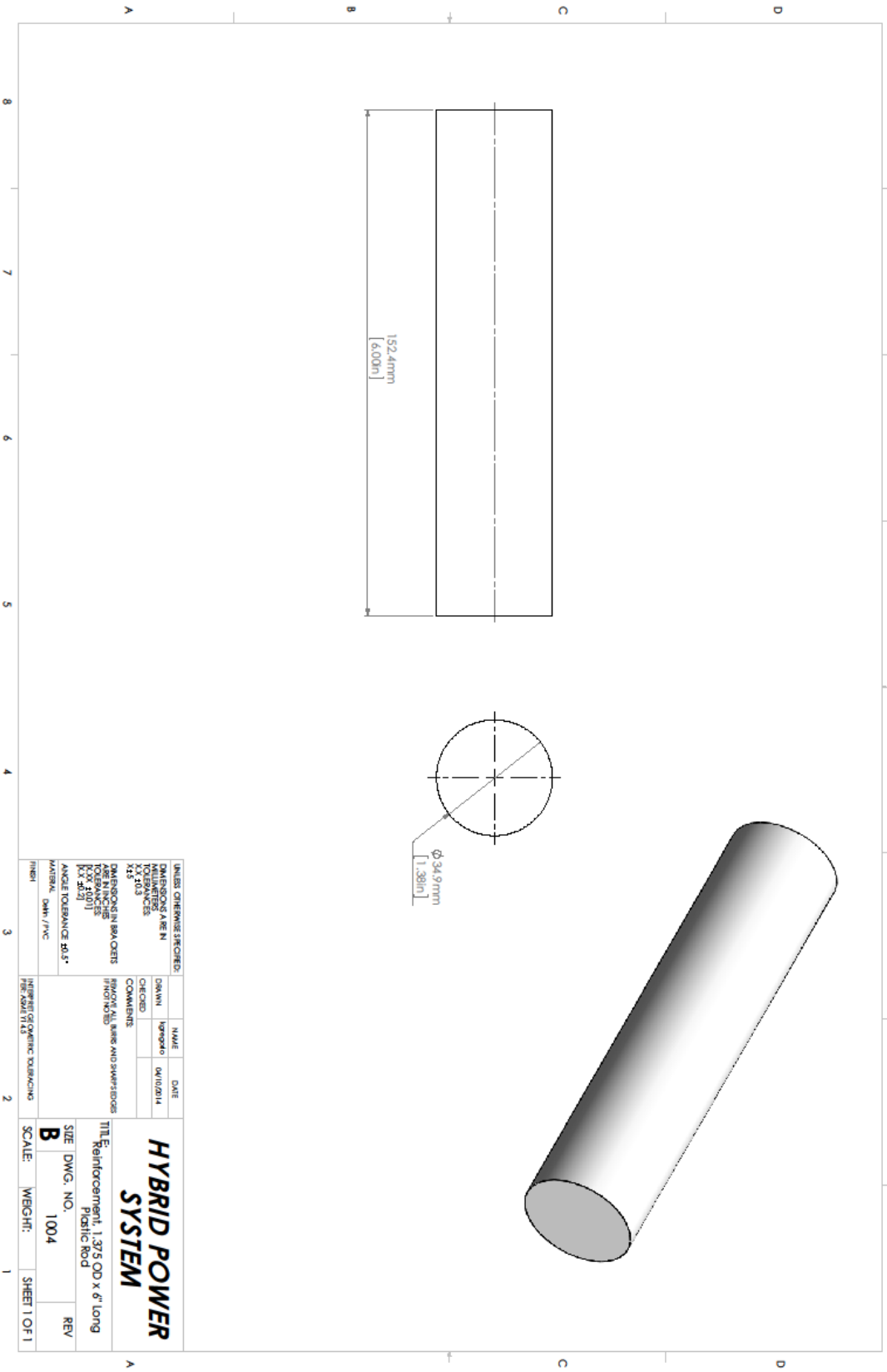


Figure 47 Plastic Rod

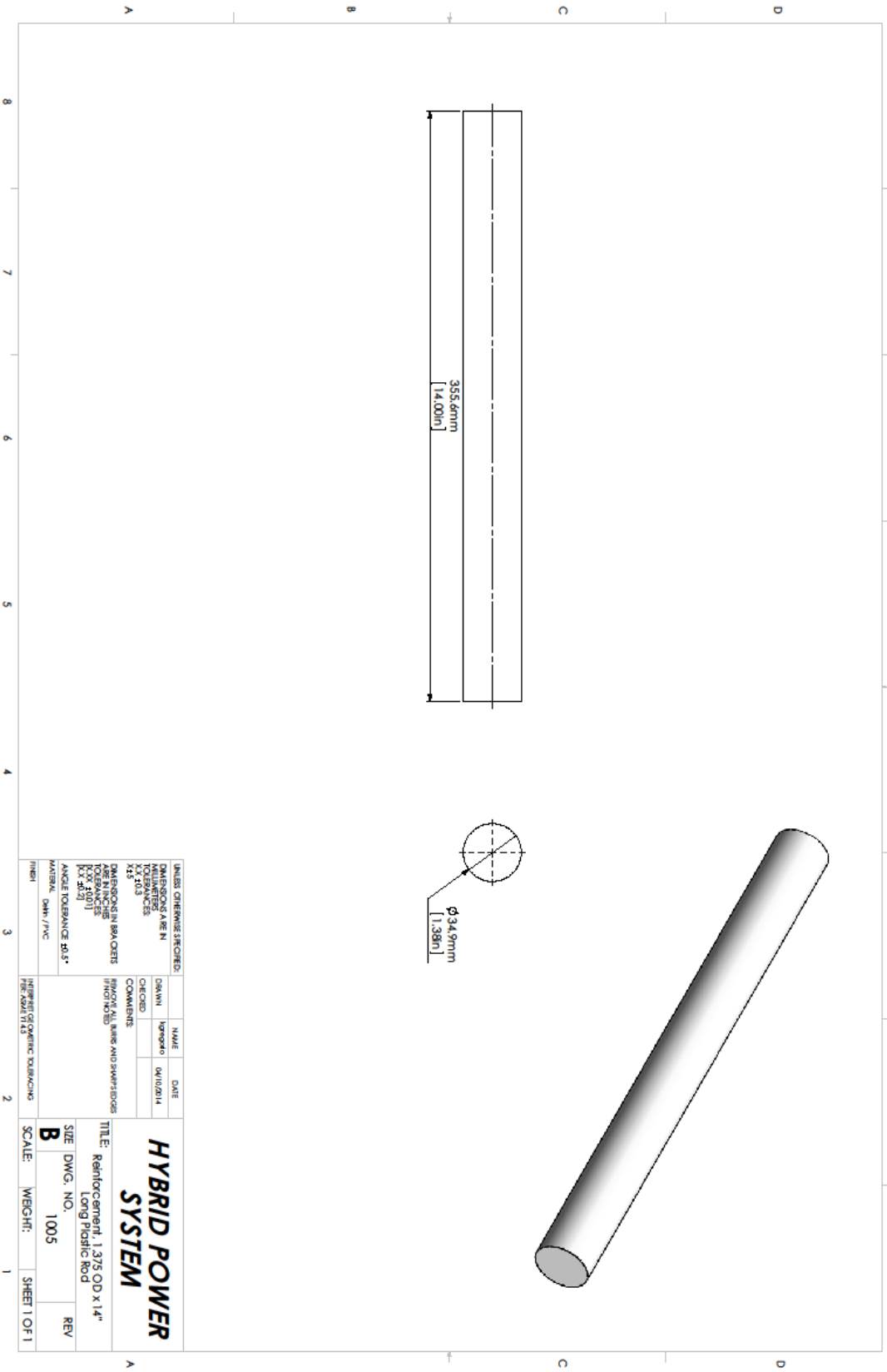


Figure 48 Long Plastic Rod

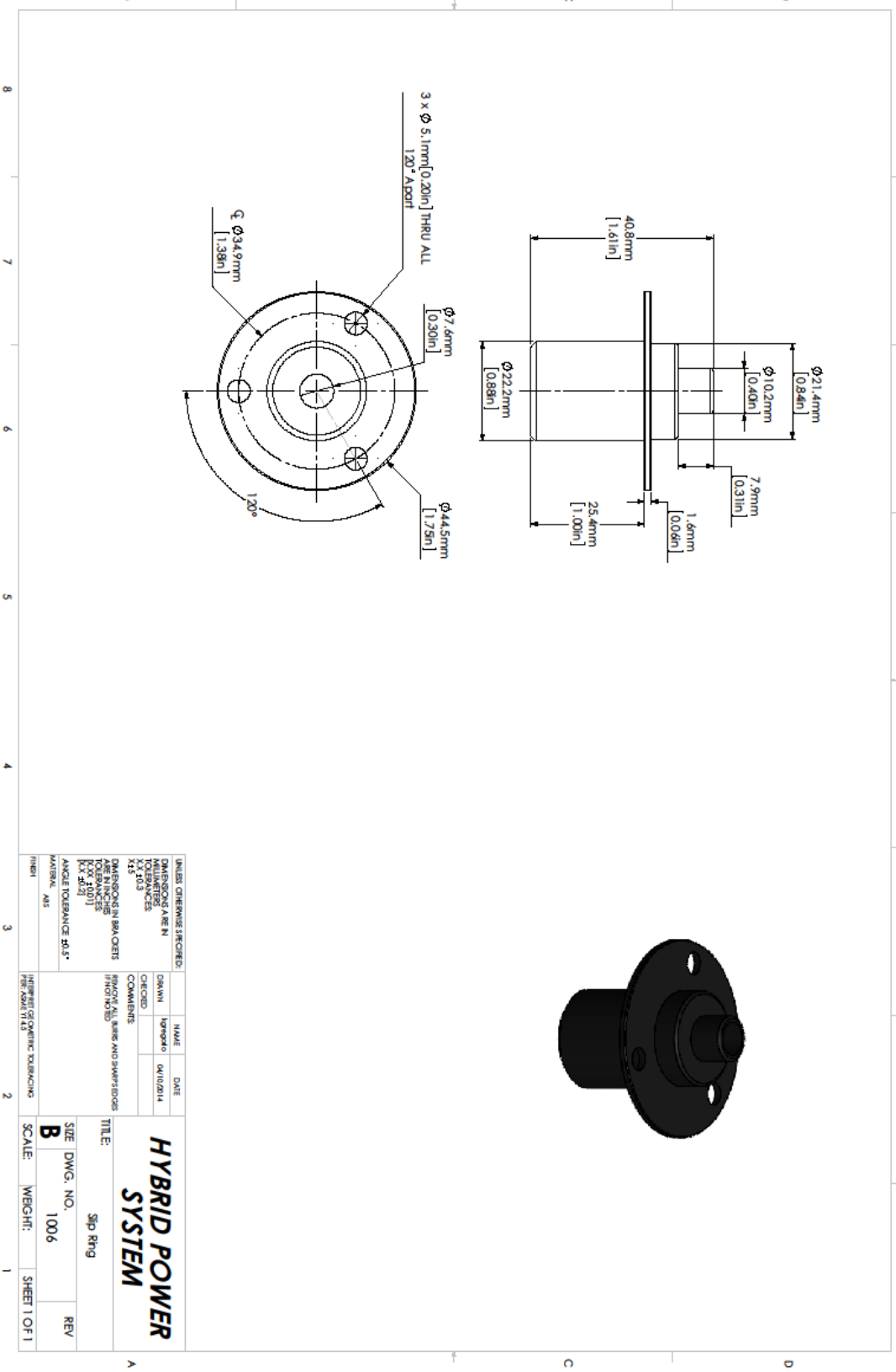


Figure 49 Slip Ring

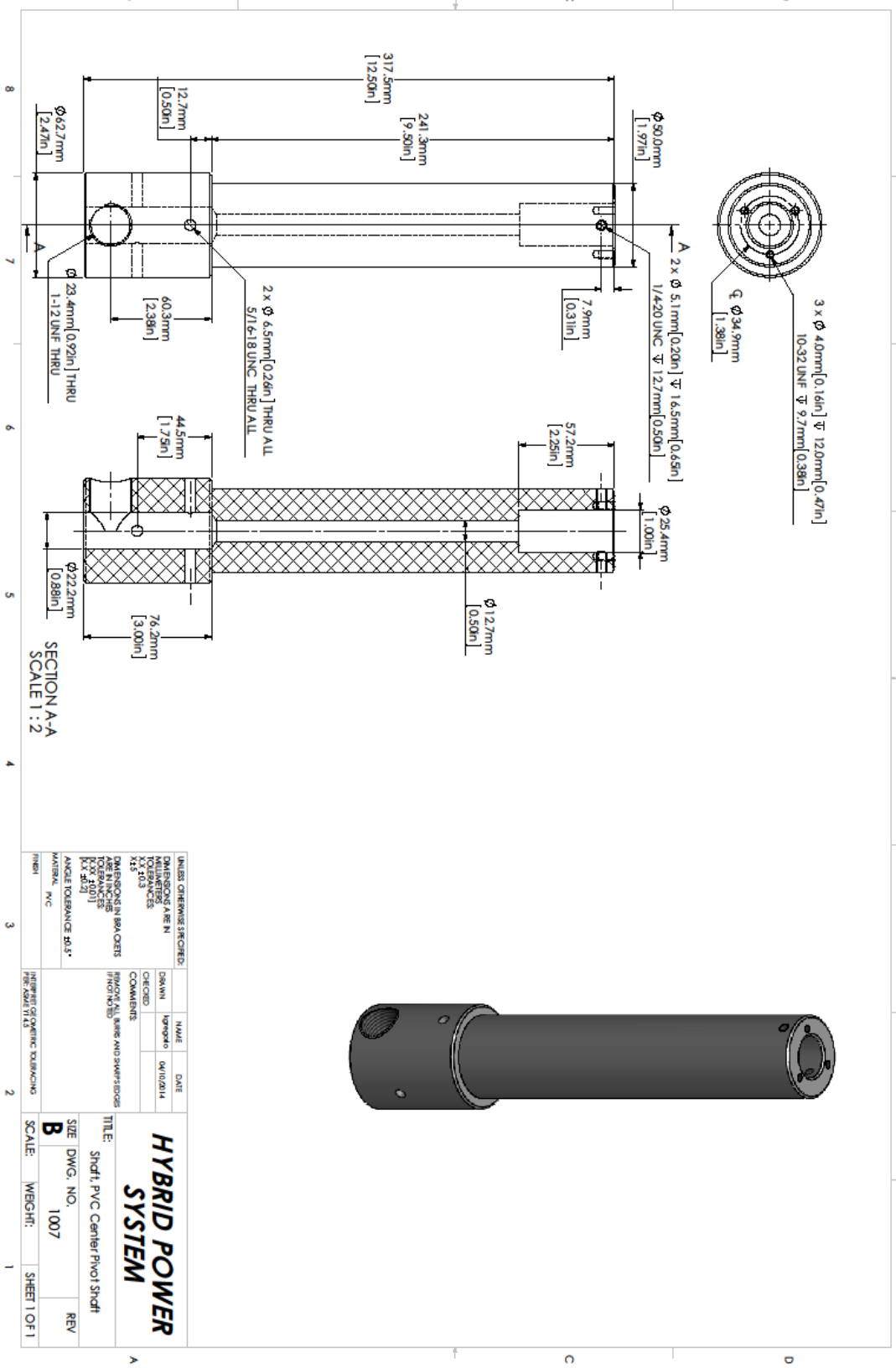


Figure 50 Center Pivot Shaft

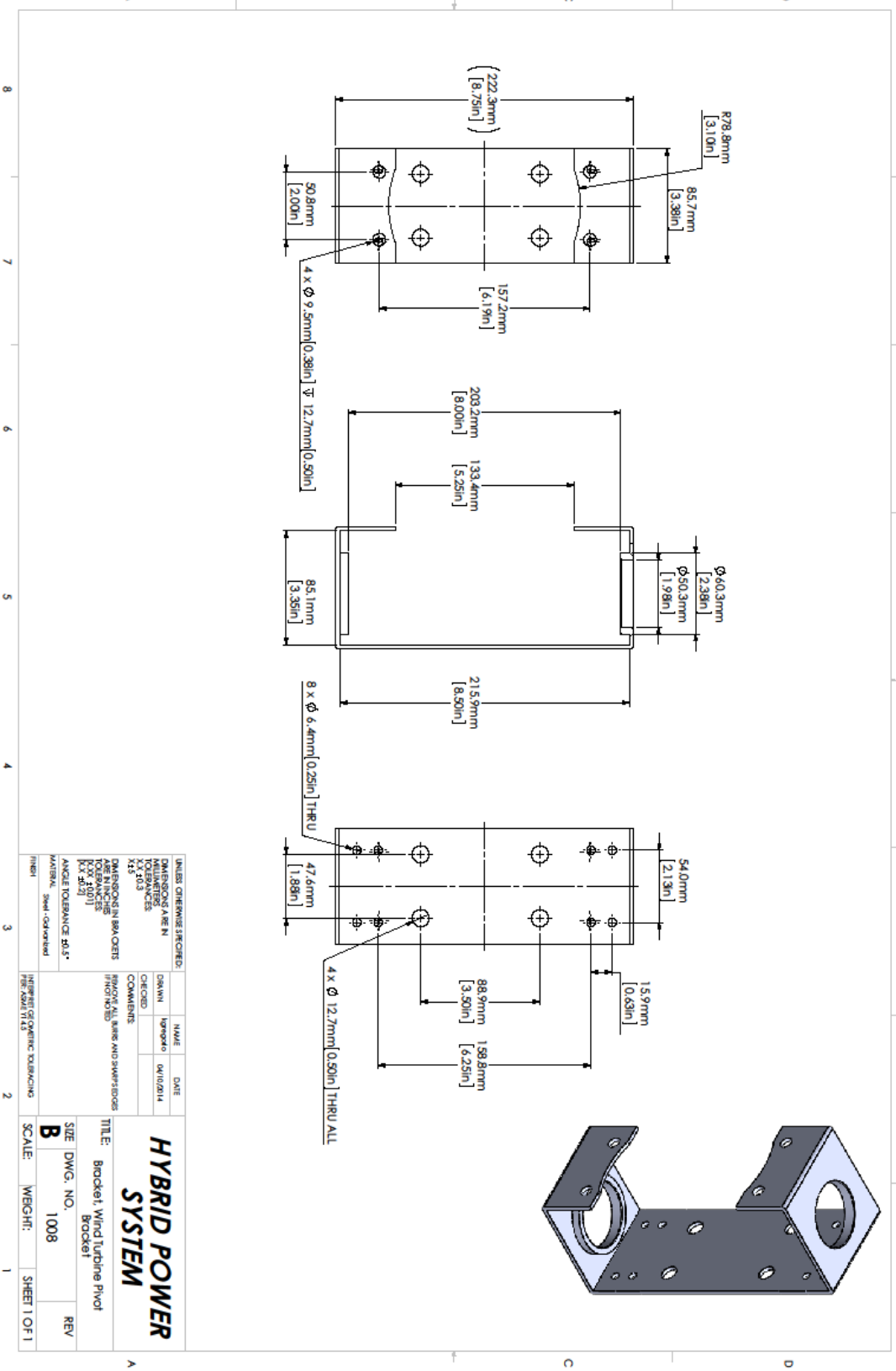


Figure 51 Pivot Bracket

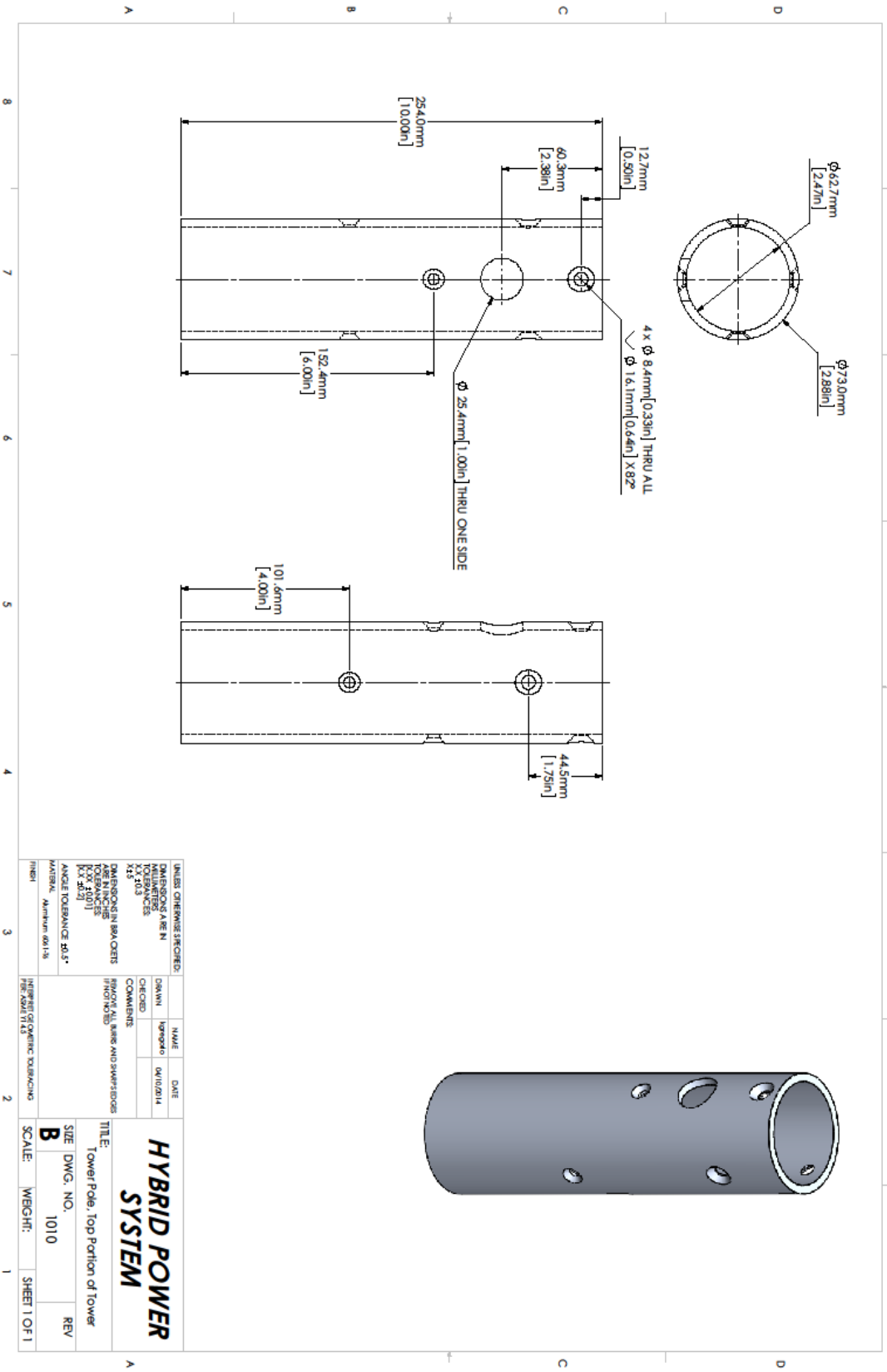


Figure 52 Tower Pole (Top Portion)

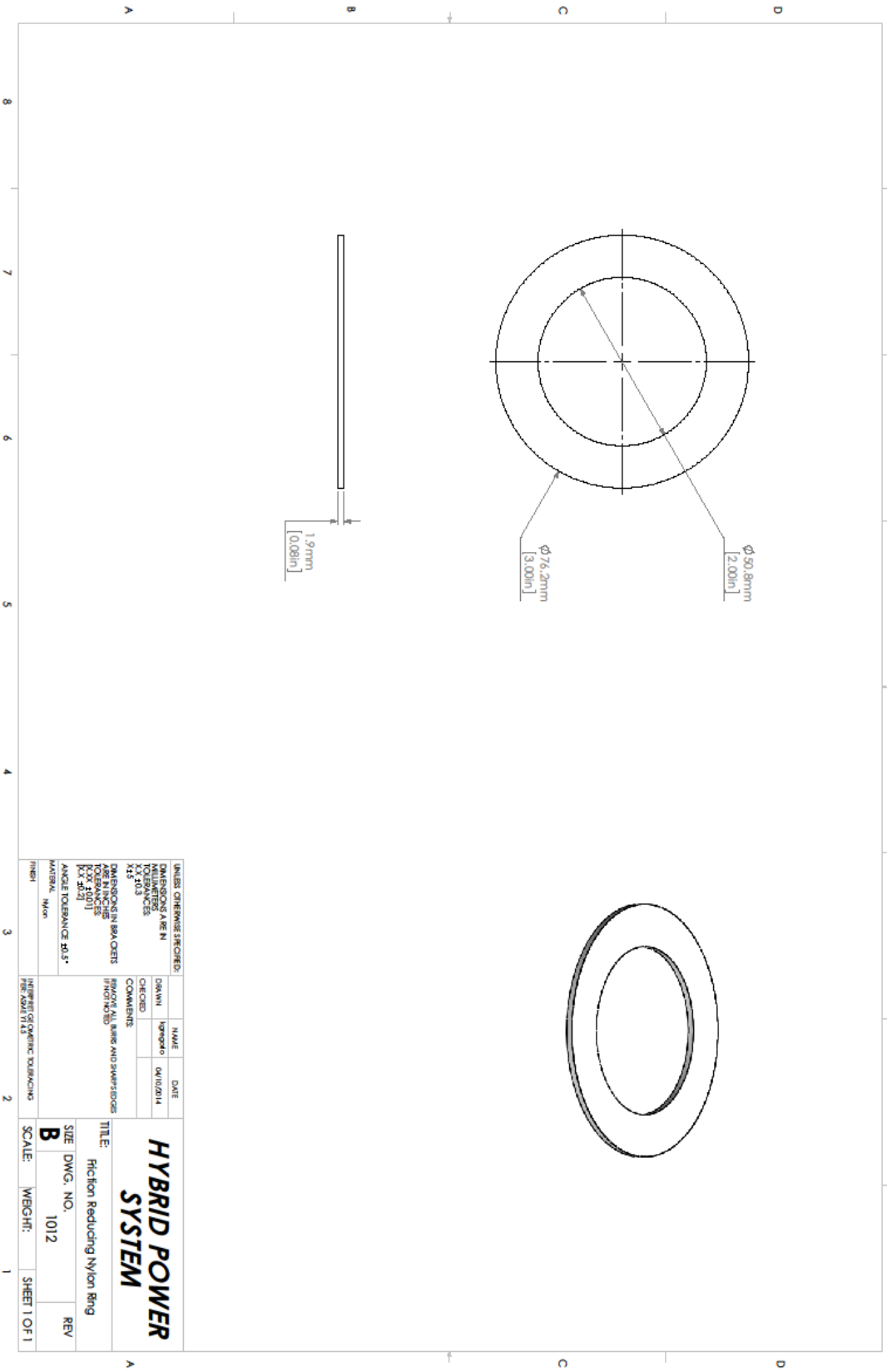


Figure 53 Nylon Ring

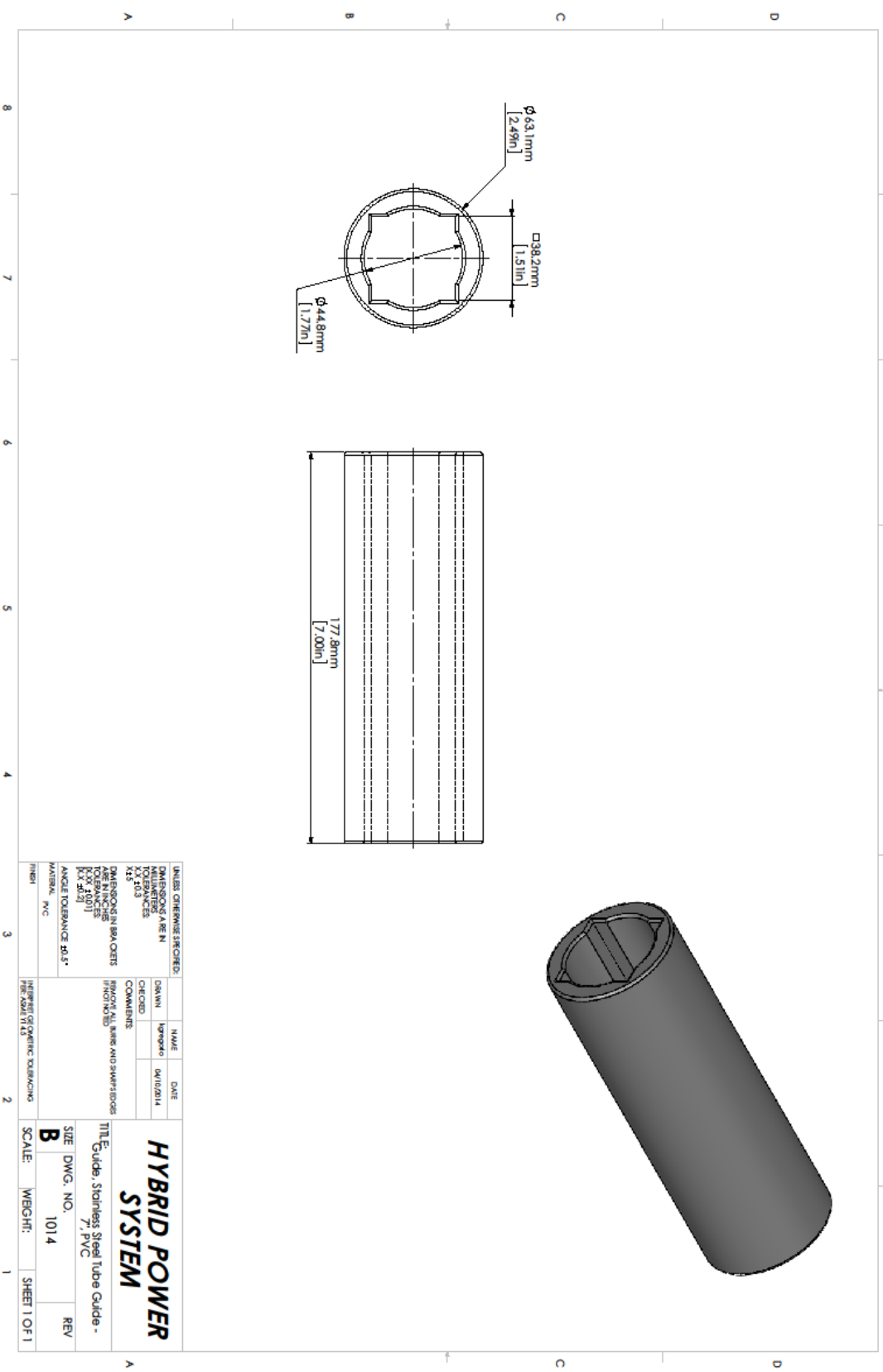


Figure 54 Steel Tube Guide A

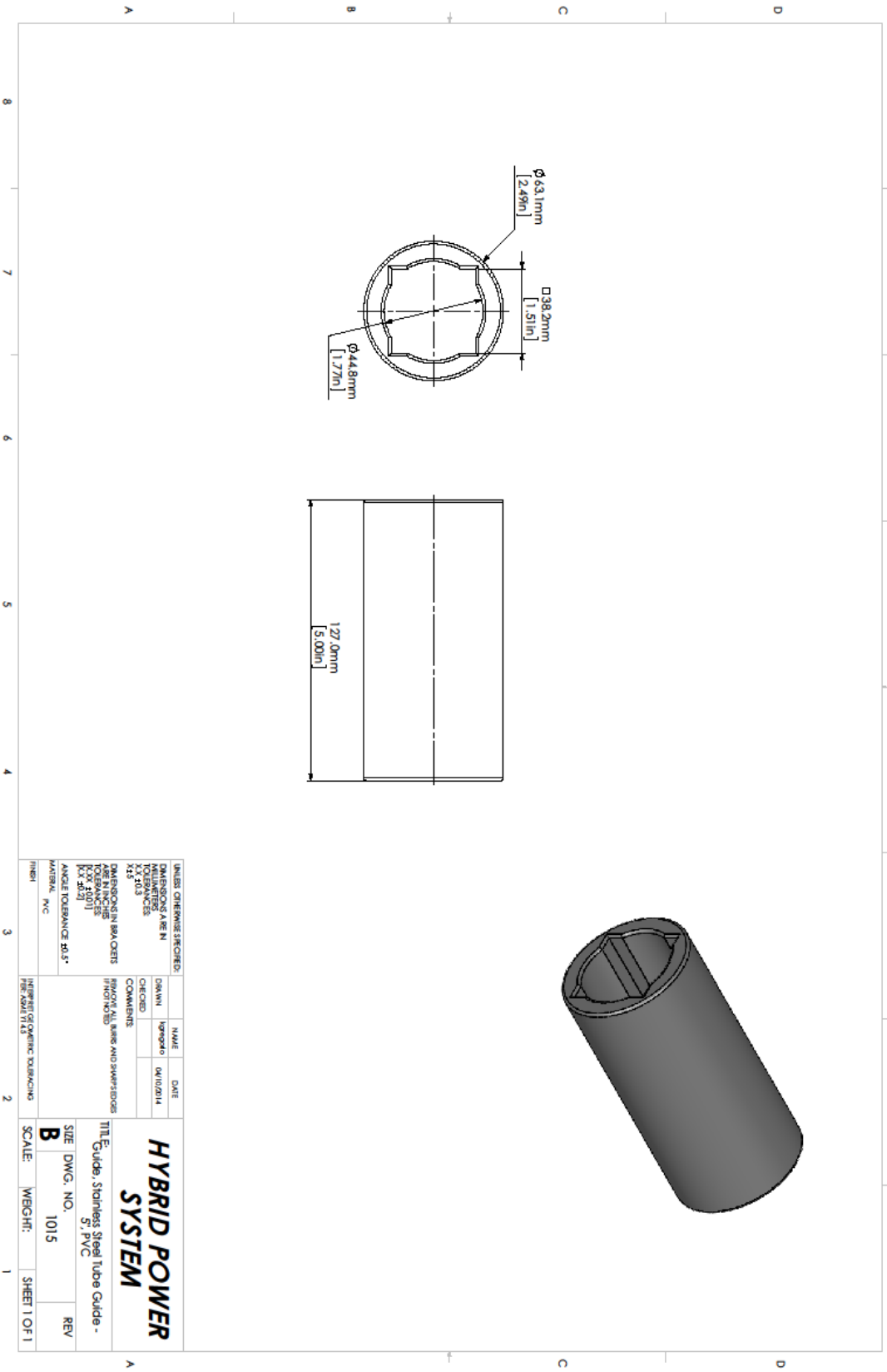


Figure 55 Steel Tube Guide B

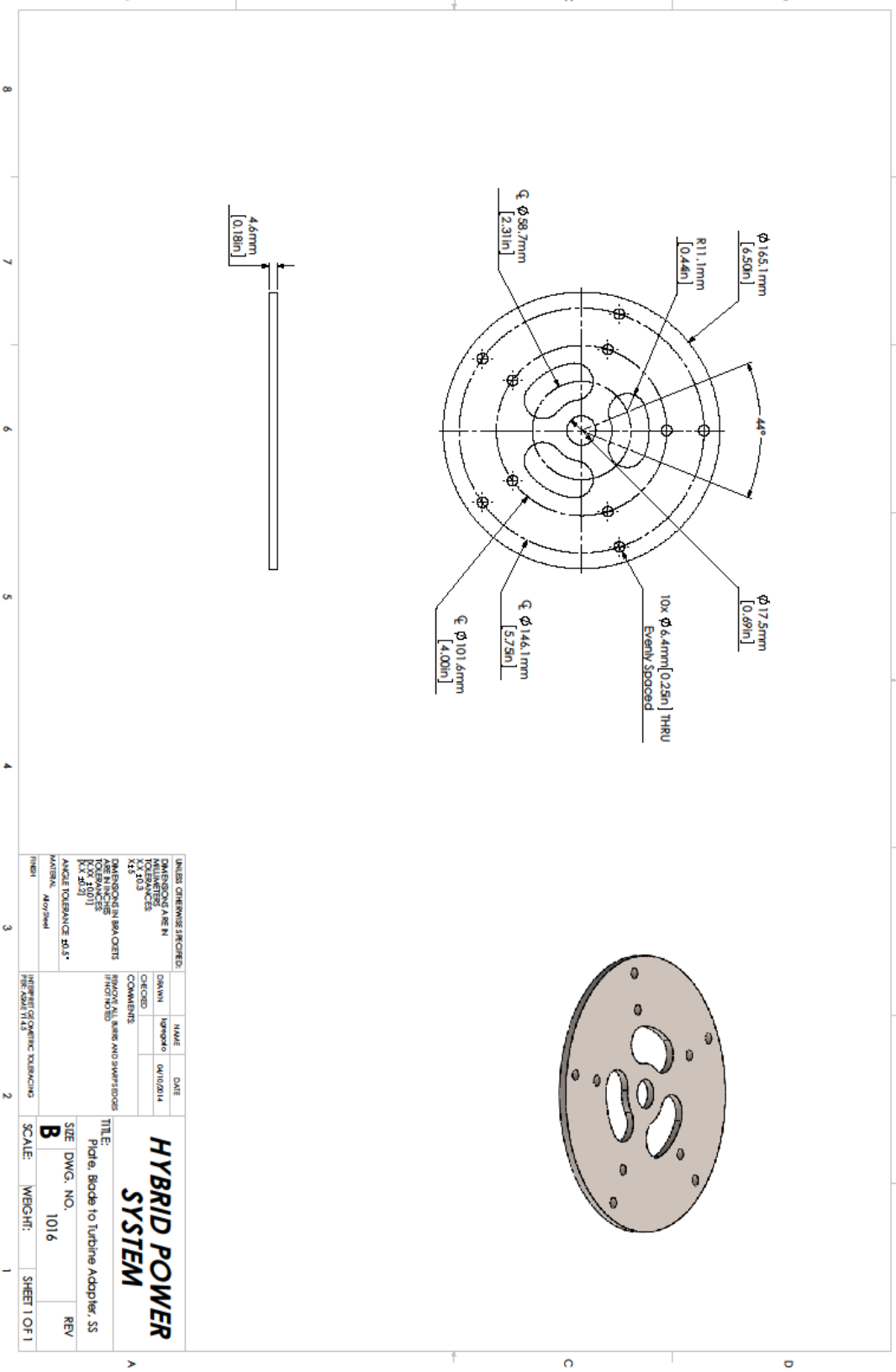


Figure 56 Blade Plate

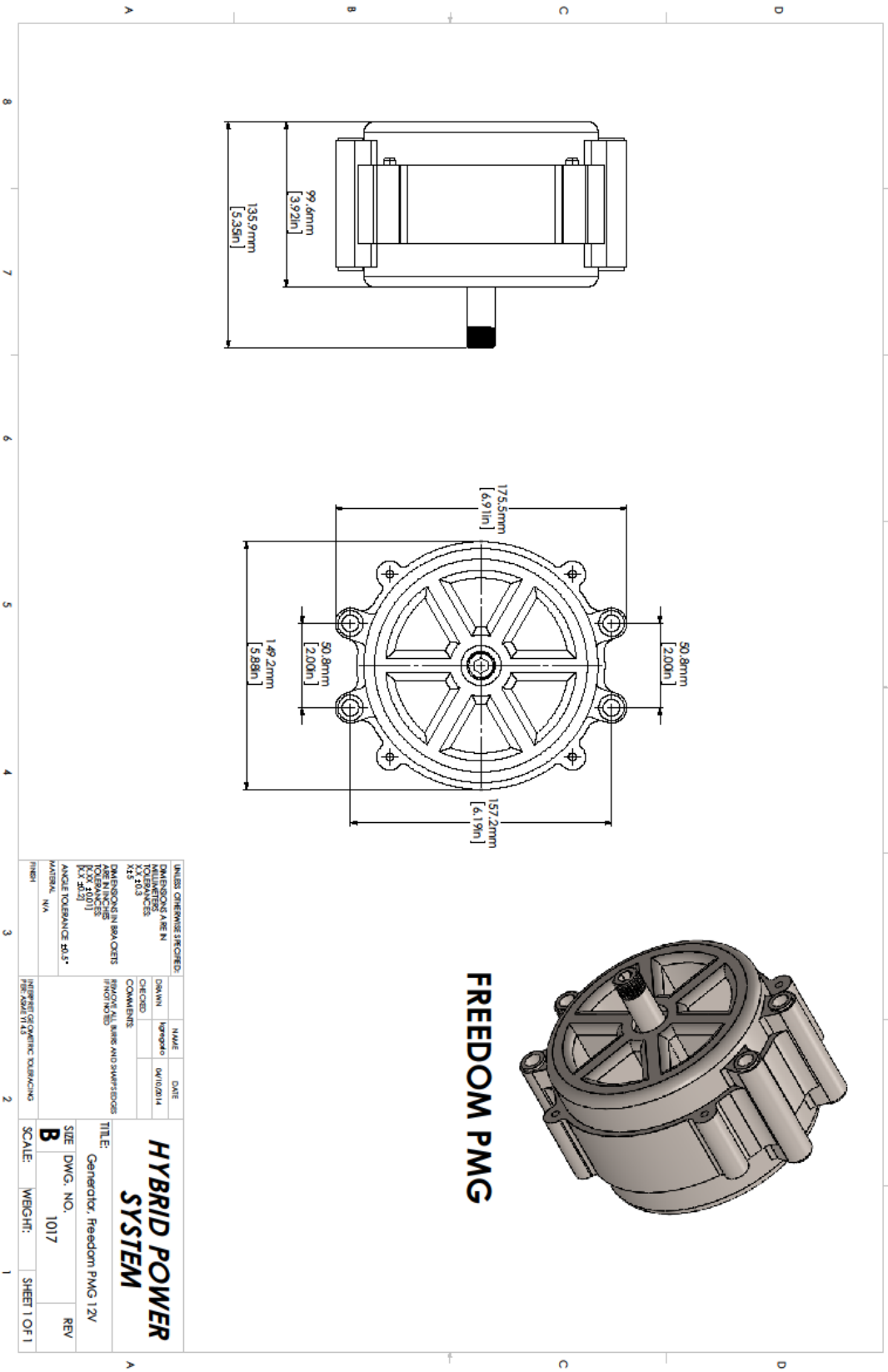


Figure 57 Freedom PMG

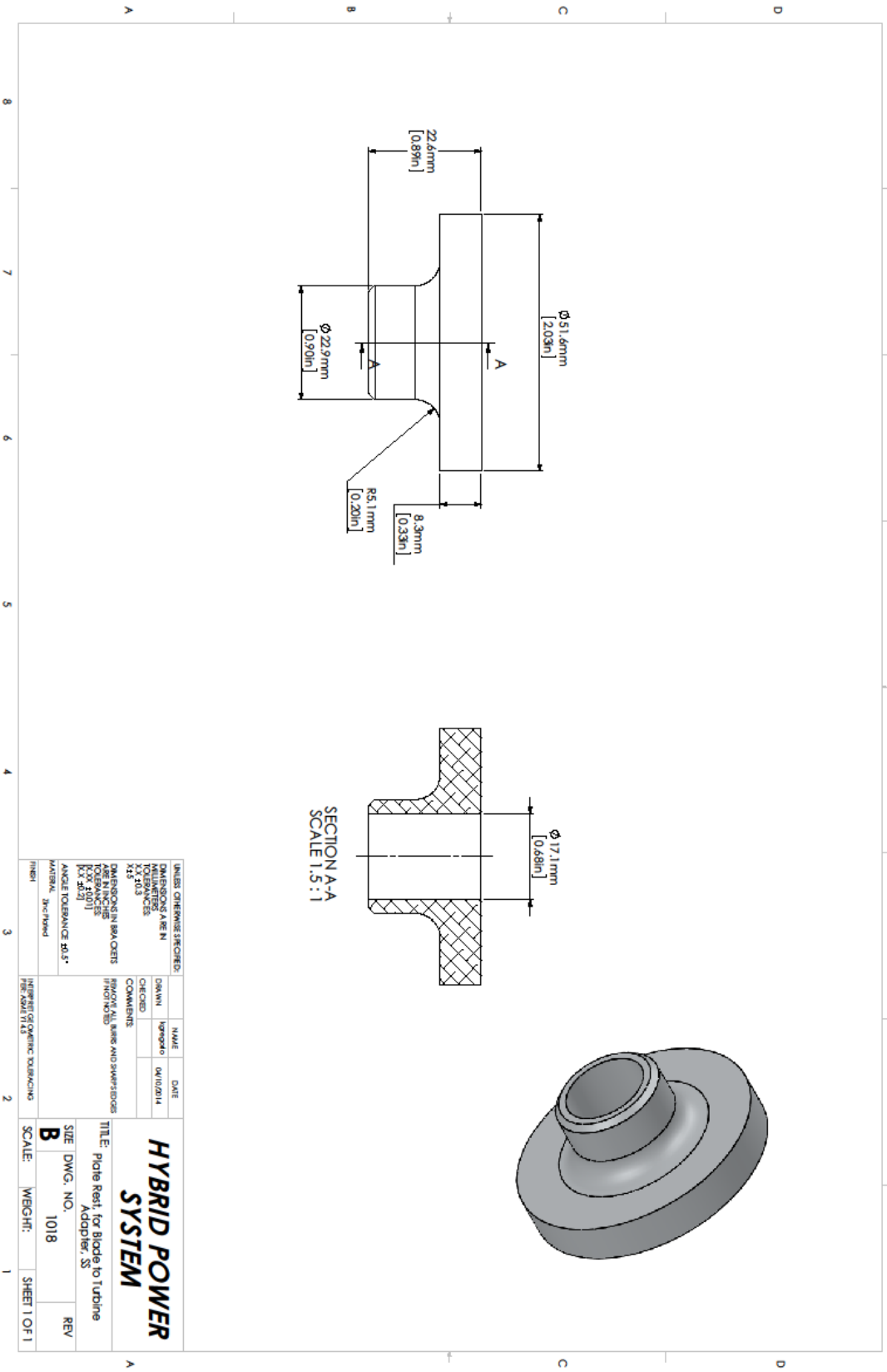


Figure 58 Pole Rest

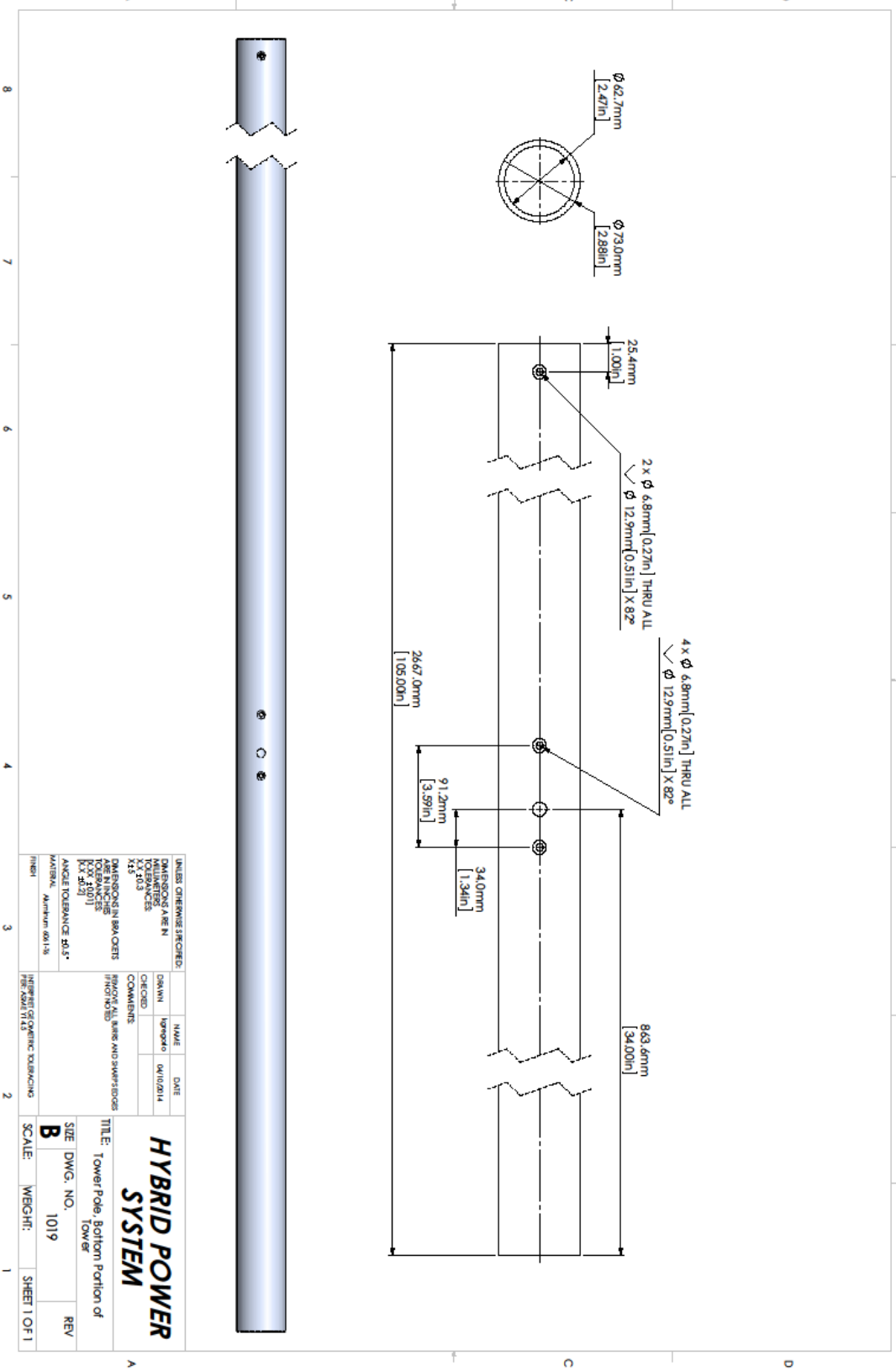


Figure 59 Tower Pole

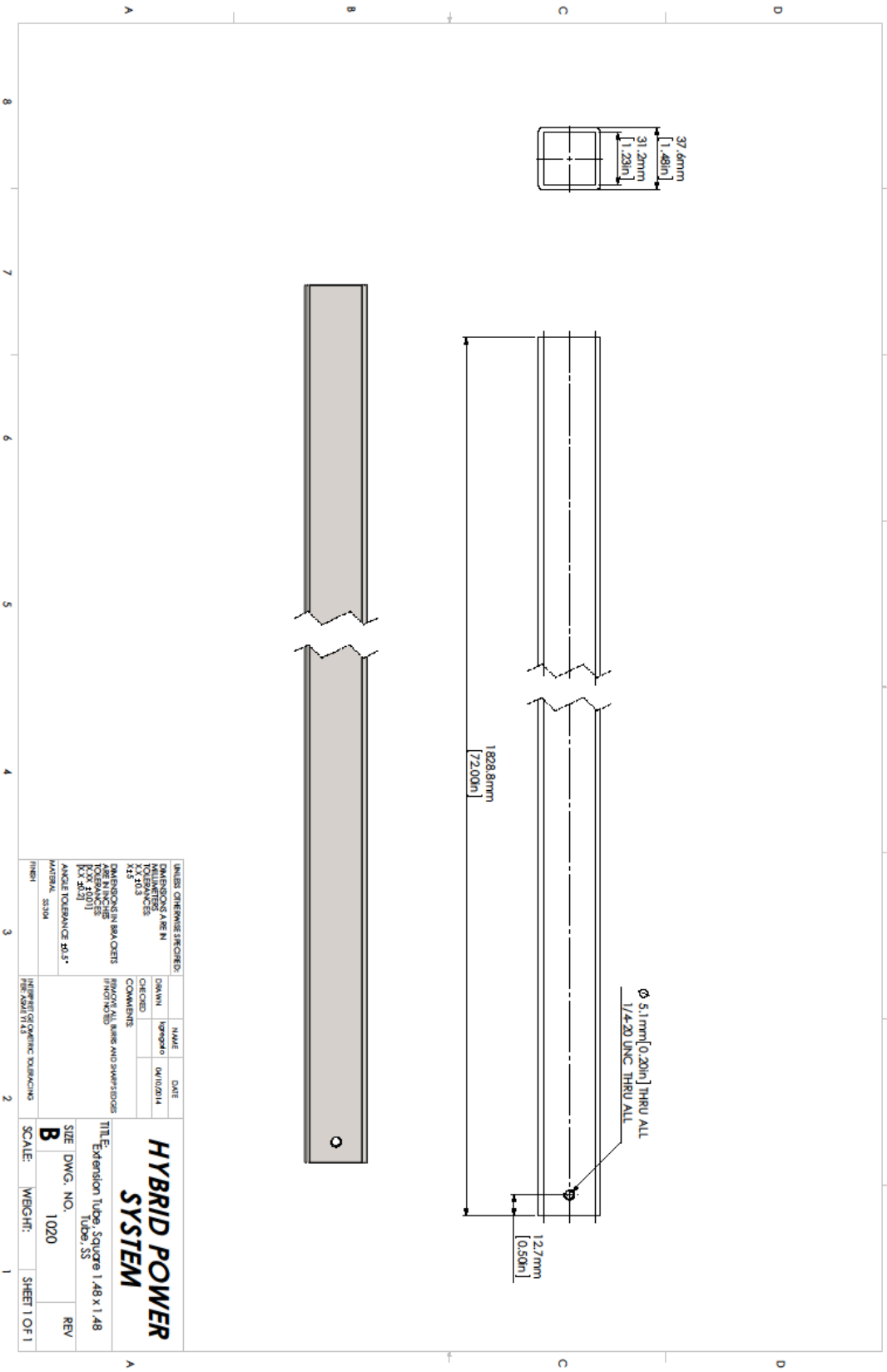


Figure 60 Extension Tube

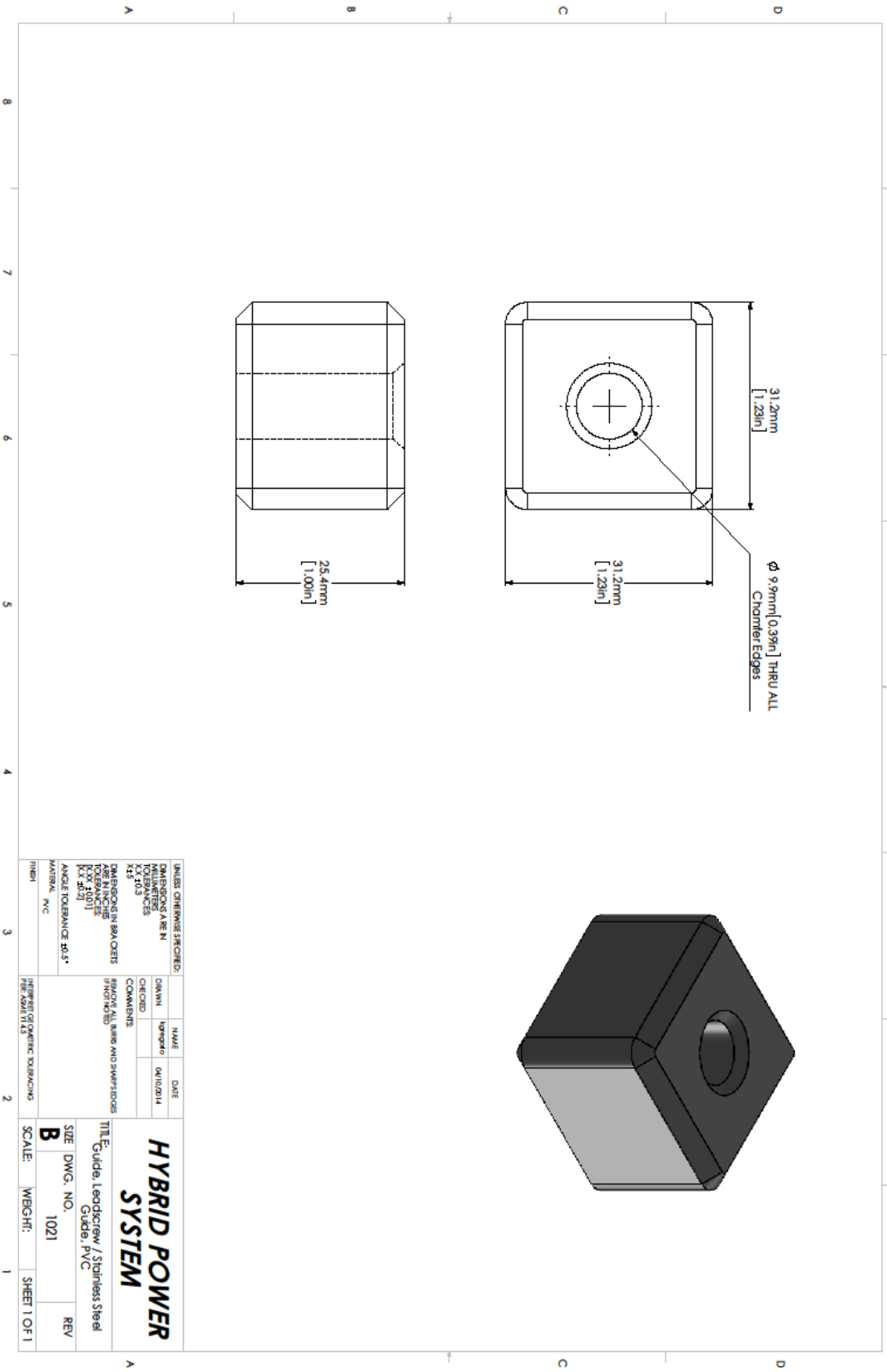


Figure 61 Guide

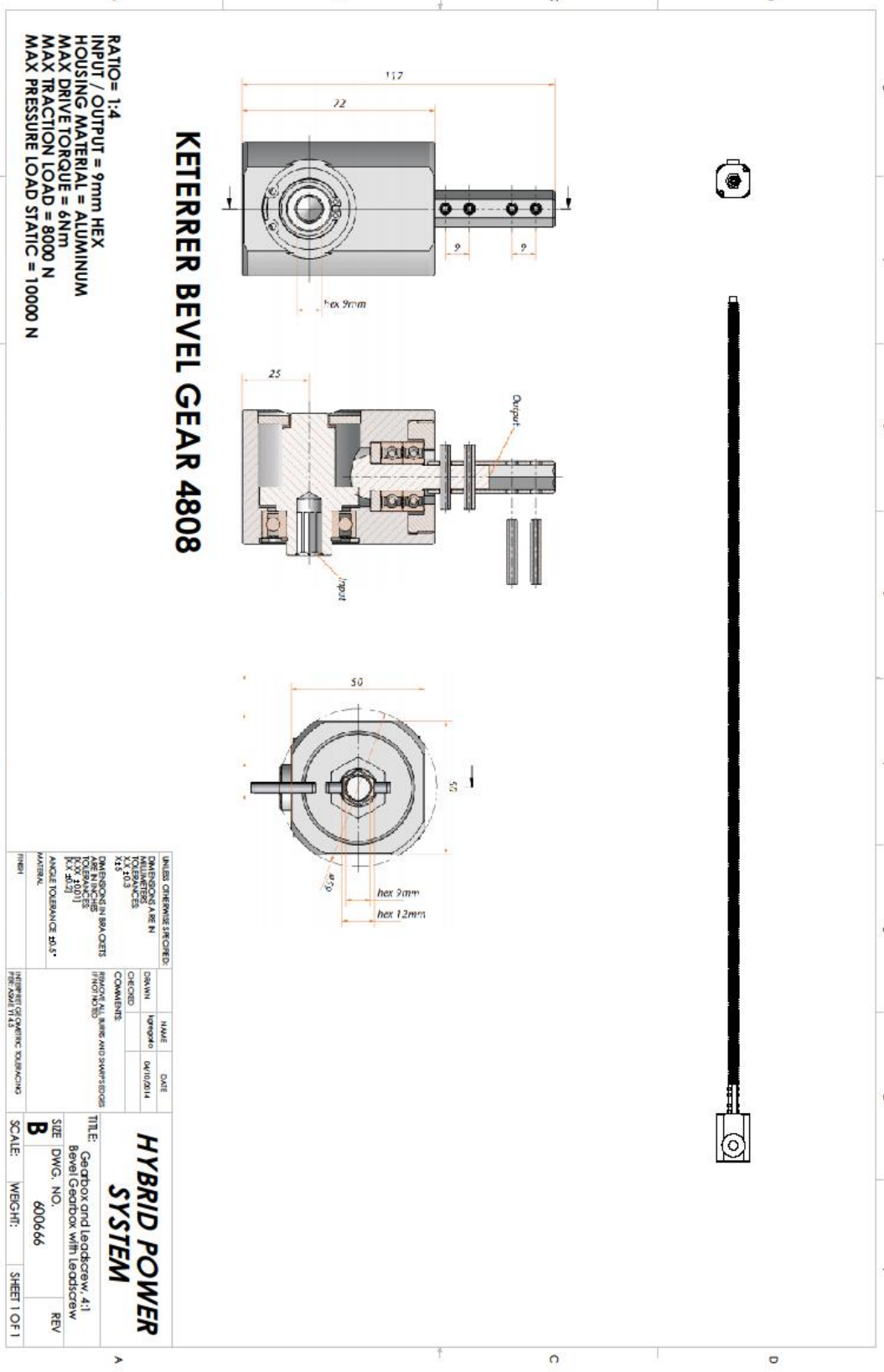


Figure 62 Gearbox

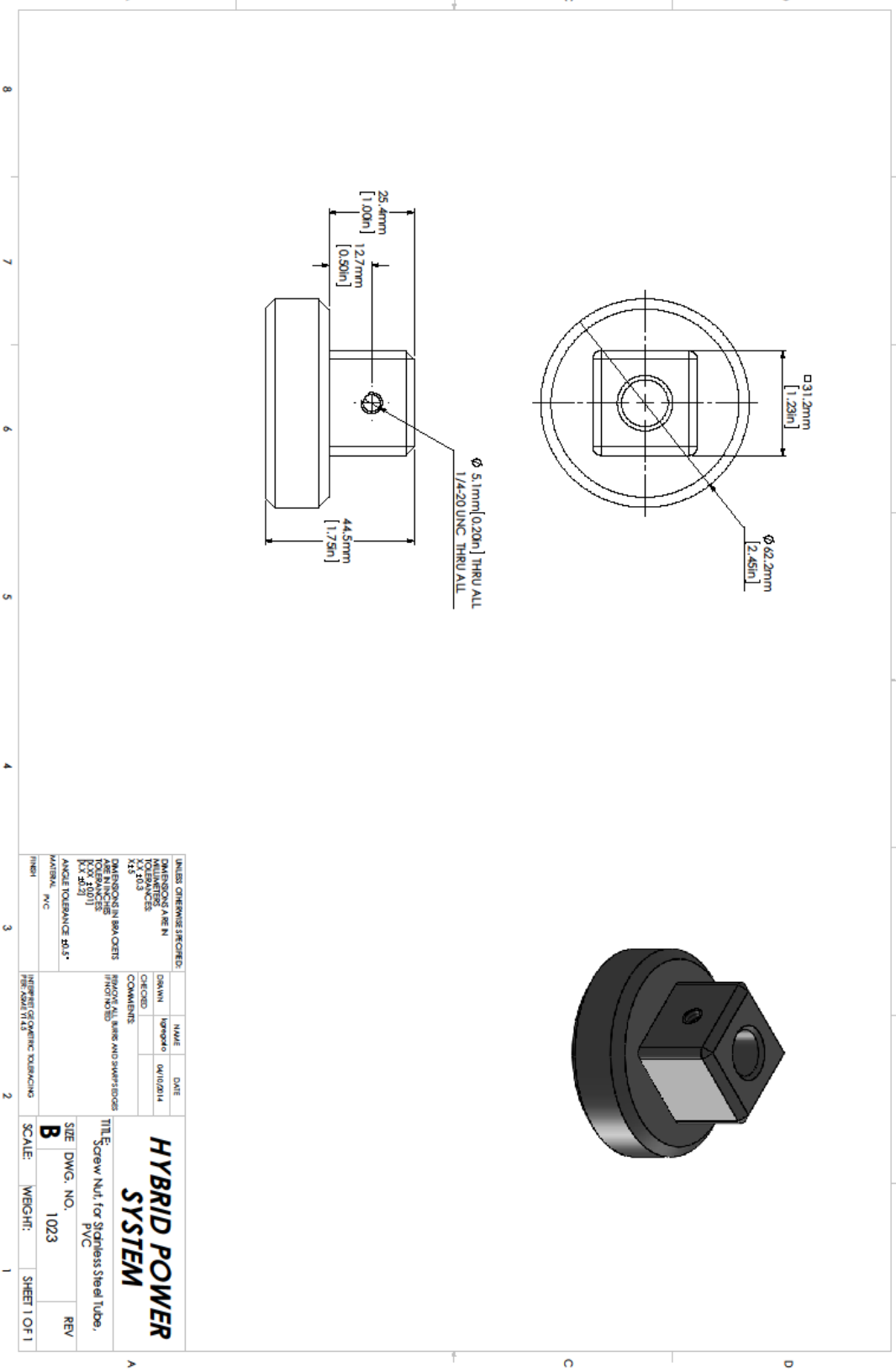


Figure 63 Screw Nut

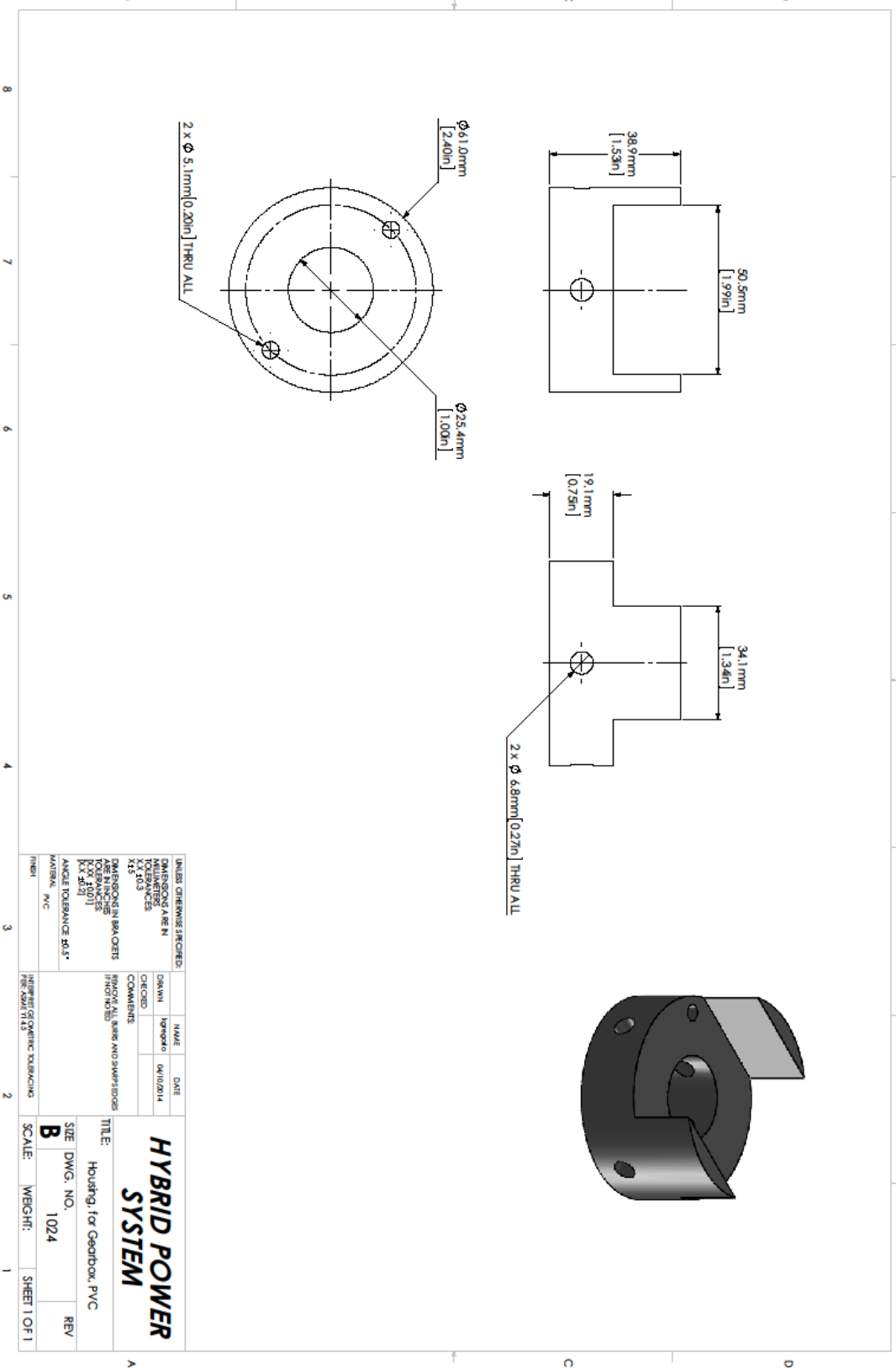


Figure 64 Gearbox Housing

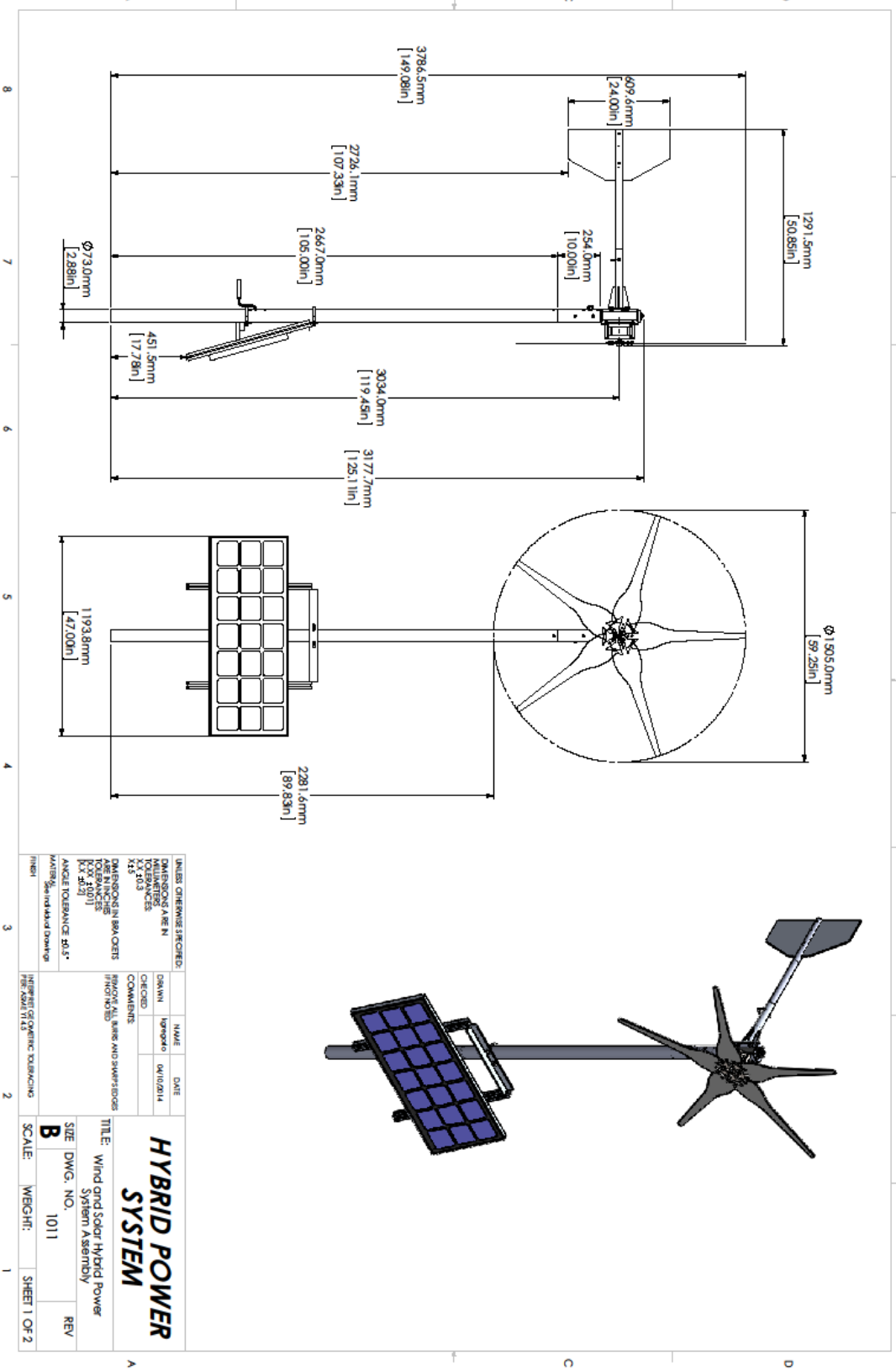


Figure 65 Assembly

Appendix A: Instruction manual

English

Congratulations on your selection of the Wind and Solar Hybrid Power System. We are certain that you will be pleased with your purchase of one of the finest hybrid power systems on the market. We want to help you get the best results from your new hybrid power system and to operate it safely. For this reason, we have dedicated a great deal of time in developing this instructions manual.

This instruction manual contains all the essential information for the user to make full use of the Solar and Wind Hybrid Power System. Inside this manual, you will find the following information:

- Assembly Instructions
- Instructions for use
- Safety Instructions / Awareness
- Maintenance Instructions
- Technical Specifications

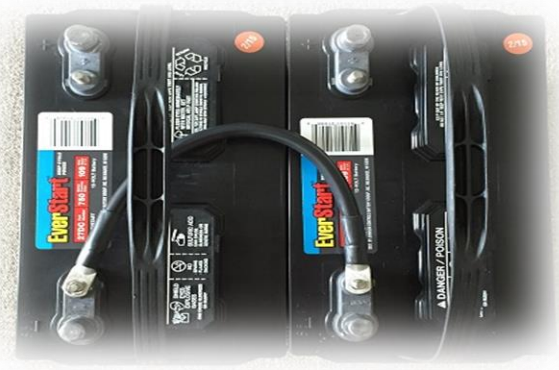
Keep this instruction manual handy, so you can refer to it at any time. This Instruction manual is considered a permanent part of the Solar and Wind Hybrid Power System and should remain with the system if resold.

Assembly Instruction for the Electrical Components

In this section, the steps for connecting the systems electrical components. For demonstration purpose all the wiring will be done outside the battery box. The following step can repeated when installing the components inside the battery box.

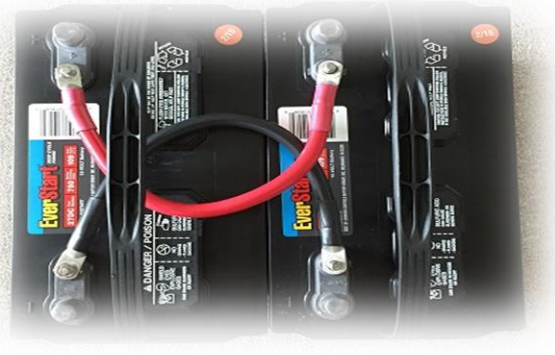
Step 1:

Place the two batteries next to each other and use the provided (black) 2 AWG short wire to connect the negative terminal of one battery to negative terminal of the other battery (negative to negative).



Step 2:

Use the provided (red) 2 AWG short wire to connect the positive terminal of one battery to positive terminal of the other battery (positive to positive).

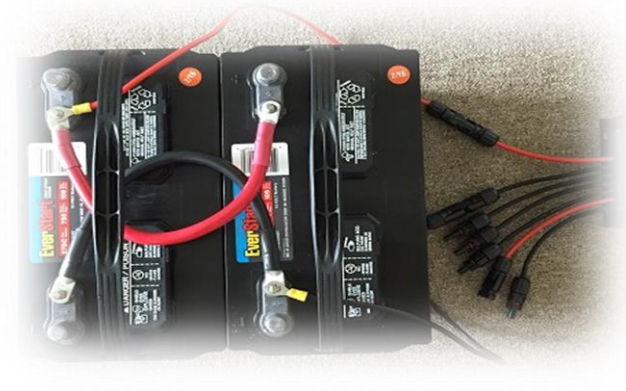


Step 3:

Use the provided (black) 10 AWG wire to connect the negative terminal of the charge controller to the negative terminal (on the right) of the battery.

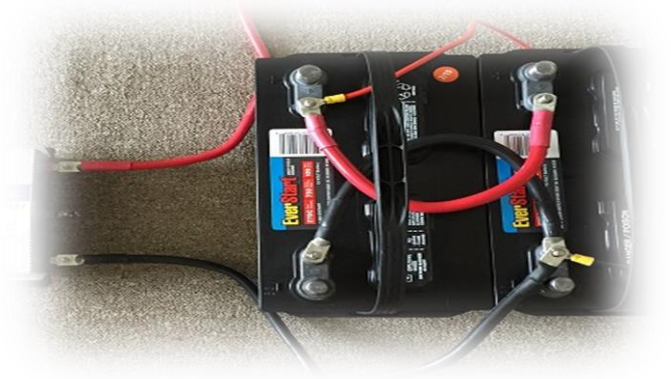
Step 4:

Use the provided (red) 10 AWG wire to connect the positive terminal of the charge controller to the positive terminal (on the left) of the battery.



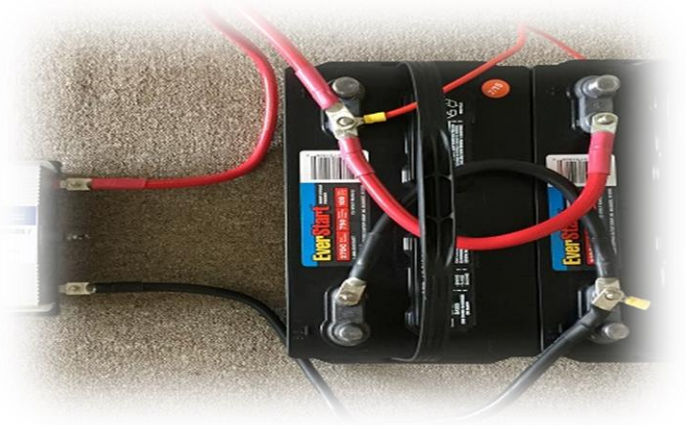
Step 5:

Use the provided (black) 2 AWG long wire to connect the negative terminal of the battery (on the right) to the negative terminal of the power inverter.



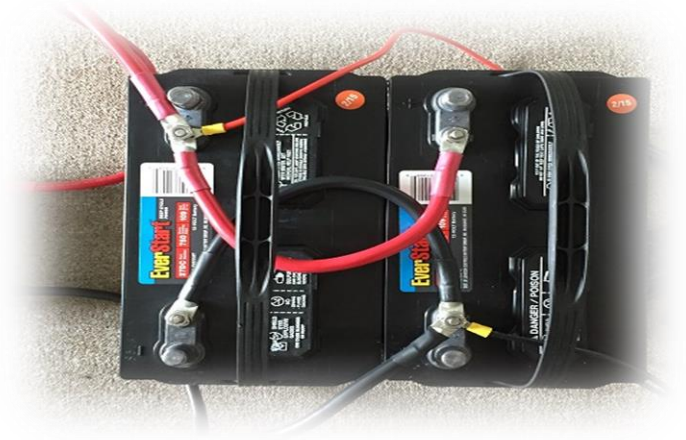
Step 6:

Use the provided (red) 2 AWG long wire to connect the positive terminal of the battery (on the left) to the positive terminal of the power inverter.



Step 7:

Place the provided cap screws on each terminal.



Step 8:

Connect the three wires from the wind turbine to the charge controller. These wires can be connected in any order.

Step 9:

Finally, connect the two wires from the solar panel to the charge controller. On this connection it is required to match black to black and red to red.

Step 10:

Repeat steps 1 to 10 by making the connections inside the battery box. The inverter and charge controller should be place on the “wall” of the battery box using the pre-drilled holes and provided screws and nuts. The box will already have an electrical fan installed to provide proper ventilations during operation.

Assembly Instruction for the Tower

This section provides the steps necessary to connect the wind turbine components (blades, tail boom and vane) and the solar panel (solar panel and mount) to the tower.

Step 1:

Remove all the components from its packaging and lay it on a flat surface.

Step 2:

Fasten the blades on the hub plate with the provided screws.

Step 3:

Place the hub plate with the assembled wind blades on the generator and fasten using the lock washer and hex nut previously on the generator.

Step 4:

Place the wind turbine facing the ground (see image below). And install the tail on the tail bracket using the provided wire lock hitch pin.

Step 5:

With the help of at least two people, carefully lift the tower of the ground and mount it on a secure base.

Step 6:

Connect the solar panel mount using the provided U-bolts. Bracket should come pre-assembled to the correct angle position, but it is recommended to verify the angle to be approximately 35 degrees. If the angle is not correct, please adjust the bracket.

Step 7:

Place the solar panel on the solar panel mount. Fasten the solar panel on the mount with the provided brackets. Make sure the brackets are fastened securely.

Step 8:

Connect the solar panel and turbine wires to the charge controller, turn on the inverter power switch and enjoy the free power

Instructions for Use

Once the system has been assembled, operating the unit is a breeze. The system will begin charging the batteries without the need for the user to do anything. Once ready to enjoy the free power, simply turn the inverter power switch to the "on" position and plug the desired electrical device.

If for any reason, the installation site is in an area in which there is a nearby wall, tree or object that is obstructing the flow of wind and creating a region of high turbulence, then simply place the crank handle into the tower's gearbox hole and crank the unit until it has reach its optimal operating position.

Maintenance Instructions

The Solar and Wind Hybrid Power System was designed so that there is minimal maintenance required.

For optimum operations and for longer product life, the following is recommended:

- Clean the face of the panels with a wet towel every other week – avoid spraying cold water onto hot panels or you could risk cranking them!
- Inspect for any dirt or debris that may collect on them as this can reduce the efficiency of the system
- Mounting and grounding components should be checked weekly for corrosion and to assure a tight and secure assembly.
- All cables and connector attachments should be inspected for damage weekly.
- Wipe the tower exterior using a towel and a surface cleaner so that the product remains aesthetically pleasing.
- Inspect the electrical power box at least once a week for any debris, water accumulation, etc. The electrical power box must be free of any debris. Use and air hose or duster to clean the inside of the electrical box. (Not doing so may void the warranty of the product).

Technical Specifications

Size:

- System Tower (tower, blades, tail , solar panel):
    - Blade Diameter: 59.25 sq.in. approximately
    - Blade Head Clearance: 90 in (non-extended) / 144 in (extended) approximately
    - Total System Height: 149 in (non-extended) / 203 in (extended) approximately
    - Tail to Blade Face: 51 in approximately
- Electrical Power Box: 32 in Length x 19 in Width x 19 in Height

Weight:

- System Tower (tower, blades, tail, solar panel): 95 lbs. approximately
- Electrical Power Box: 120 lbs. approximately
- Total Solar and Wind Hybrid Power System: 215 lbs. approximately

Generator - Freedom PMG (Permanent Magnet Generator):

- Overall Dimensions:
    - 3/8" Diameter Bolt Holes
    - 1-15/16" on center between mounting holes
    - 5-7/8" Outer Diameter Width
    - 6-5/16" Tall
- Brushless
- Skewed stator core with high grade electrical steel and heavy duty copper windings
- Polished aluminum case
- Produces battery voltage at approximately 266 RPM
- Produces twice the battery voltage at approximately 506 RPM
- Manufactures in the USA

Solar Panel – Renogy 100 Watt Panel (RNG-100D):

- Overall Dimensions:
    - 47 in Length x 21.3 in Width x 1.4 in Height
- Solar Cell: Monocrystalline (4.9 x 4.9 in)
- Number of Cells: 36
- Weight: 16.5 lbs.
- Frame: Anodized aluminum alloy

- Connectors: MC4 connectors
- Maximum Power at STC (Pmax): 100 W
- Optimum Operating Voltage (Vmp): 18.9 V
- Optimum Operating Current (Imp): 5.29 A
- Maximum System Voltage: 600 VDC

Safety Instructions / Awareness

- The Solar and Wind Hybrid Power System produces enough electric power to cause serious shock or electrocution if misused. Please operate it responsibly.
- DO NOT use the hybrid power system in wet conditions, such as rain and snow, or near a pool or sprinkler system.
- DO NOT operate the wind turbine when hands are wet. Keep the electrical box dry and free of debris.
- DO NOT leave the system out in the open during times of bad weather.
- In case of a storm, store the hybrid system in-doors. At minimum, cover the wind turbine tower and the solar panels and disconnect the electrical box from the system.
- DO NOT reach out to manually stop the wind turbine blades (doing so may results in bodily injury, as the blades may have sharp edges and may be rotating at high speeds.
- DO NOT attempt to do the installation individually. Always ask for assistance when installing the tower on a base.
- Keep connecters dry and clean, and ensure that connector caps are hand tight before connecting the modules. DO NOT attempt to make connections with wet, soiled or otherwise faulty connectors.

*All specifications are subject to change without notice. Please check with your local supplier for exact specifications.

*Product colors and accessories are subject to change without notice.

*Manufacturer is not responsible for damages of other devices when plugged into the inverter of the Solar and Wind Hybrid Power System.

Spanish

Enhorabuena por la selección del sistema de energía híbrida eólica y solar. Estamos seguros de que usted estará satisfecho con su compra de uno de los mejores sistemas de energía híbridos en el mercado. Queremos ayudarle a obtener los mejores resultados con su nuevo sistema de energía híbrida y operarlo con seguridad. Por esta razón, hemos dedicado una gran cantidad de tiempo en el desarrollo de la presente instrucción.

Este manual de instrucciones contiene toda la información esencial para el usuario hacer un uso completo de la solar híbrido sistema de energía eólica y. Dentro de este manual, encontrará la siguiente información:

- Instrucciones de montaje
- Instrucciones de uso
- Instrucciones de seguridad / Conciencia
- Instrucciones de mantenimiento
- Especificaciones Técnicas

Guarde este manual de instrucciones a mano, para que pueda referirse a ella en cualquier momento. Este manual de instrucciones se considera una parte permanente del Viento y Solar Hybrid Power System y debe permanecer con el sistema en caso de reventa.

Instrucciones de montaje para los componentes eléctricos

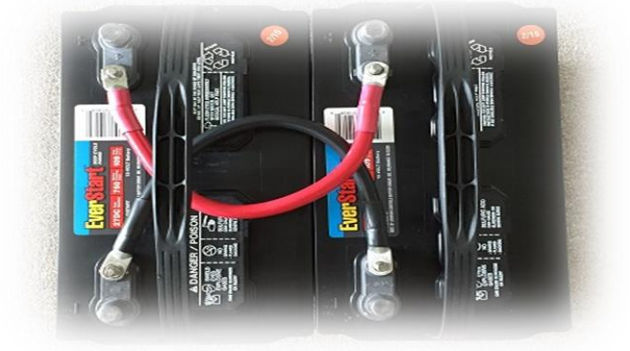
En esta sección, los pasos para la conexión de los sistemas de componentes eléctricos. Para fines de demostración se hará todo el cableado fuera de la caja de la batería. El siguiente paso puede repetirse al instalar los componentes dentro de la caja de la batería.

Paso 1:

Coloque las dos pilas lado de la otra y utilizar el (negro) 2 cable corto AWG proporcionado para conectar el terminal negativo de una batería al terminal negativo de la otra batería (negativo a negativo).

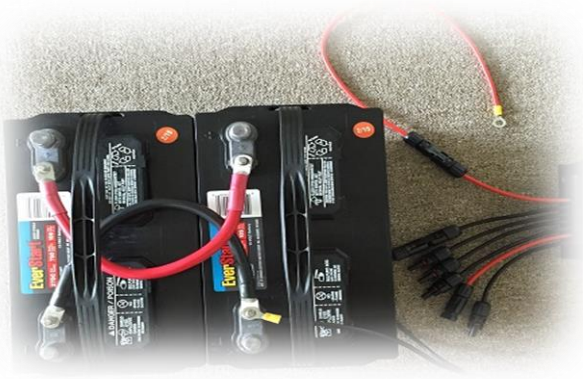
Paso 2:

Utilice el (rojo) 2 cable corto AWG suministrado para conectar el terminal positivo de una batería al terminal positivo de la otra batería (positivo a positivo).



Paso 3:

Utilice el (negro) 10 AWG suministrado para conectar el terminal negativo del regulador de carga a la terminal negativa (a la derecha) de la batería.

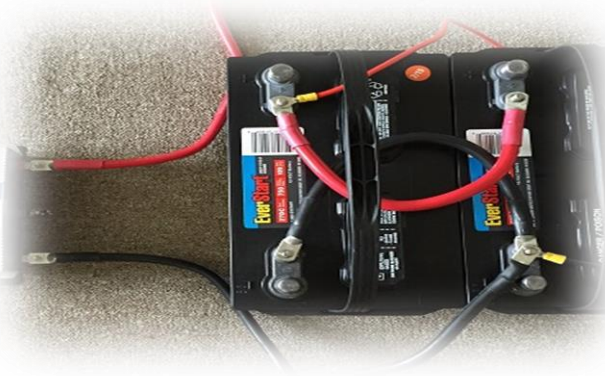


Paso 4:

Utilice la (rojo) 10 AWG suministrado para conectar el terminal positivo del regulador de carga a la terminal positiva (a la izquierda) de la batería.

Paso 5:

Utilice el (negro) 2 hilos largo AWG suministrado para conectar el terminal negativo de la batería (a la derecha) al terminal negativo del inversor de potencia.

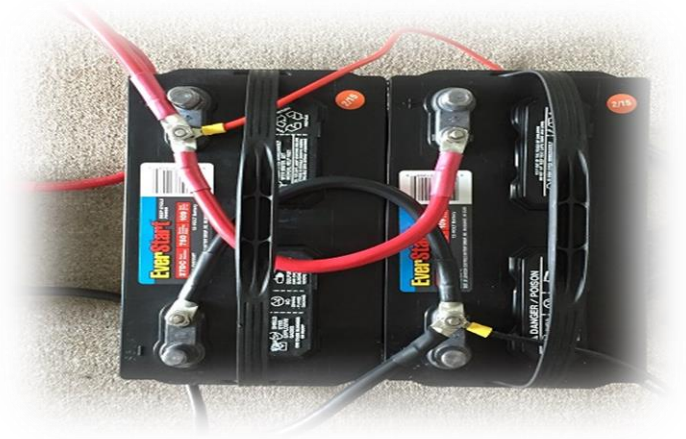


Paso 6:

Utilice el (rojo) 2 hilos largo AWG suministrado para conectar el terminal positivo de la batería (a la izquierda) a la terminal positiva del inversor de potencia.

Paso 7:

Coloque los tornillos suministrados en cada terminal.



Paso 8:

Conecte los tres cables de la turbina de viento para el regulador de carga. Estos cables se pueden conectar en cualquier orden.

Paso 9:

Por último, conecte los dos cables del panel solar para el regulador de carga. En este sentido, es necesario para que coincida con negro con negro y rojo con rojo.

Paso 10:

Repita los pasos 1 a 10, haciendo las conexiones dentro de la caja de la batería. El inversor y el regulador de carga debe ser lugar en el "muro" de la caja de la batería usando los agujeros previamente perforados y provistos tornillos y tuercas. La caja tendrá ya un ventilador eléctrico instalado para proporcionar ventilación adecuada durante la operación.

Instrucción de Asamble de la Torre

Esta sección proporciona los pasos necesarios para conectar los componentes de los aerogeneradores (palas, auge de la cola y paletas) y el panel solar (panel solar y montaje) a la torre.

Paso 1:

Retire todos los componentes de su embalaje y colocarlo sobre una superficie plana.

Paso 2:

Fije las palas en la placa del cubo con los tornillos suministrados.

Paso 3:

Coloque la placa del cubo con las palas de aerogeneradores montados en el generador y apriete utilizando la arandela de seguridad y tuerca hexagonal previamente en el generador.

Paso 4:

Coloque la turbina de viento hacia el suelo (ver imagen de abajo). E instalar la cola en el soporte de la cola utilizando el cable proporcionado pasador de enganche de bloqueo.

Paso 5:

Con la ayuda de al menos dos personas, levante con cuidado la torre de la tierra y montarlo en una base segura.

Paso 6:

Conecte el panel solar de montaje utilizando los tornillos U suministrados. Soporte debe venir pre-ensamblada a la posición del ángulo correcto, pero se recomienda verificar el ángulo de aproximadamente 35 grados. Si el ángulo no es correcto, por favor, ajuste el soporte.

Paso 7:

Coloque el panel solar en el panel solar de montaje. Fije el panel solar en el monte con los soportes suministrados. Asegúrese de que los soportes estén bien apretados.

Paso 8:

Conecte los cables del panel y de la turbina de energía solar para el regulador de carga, encienda el interruptor de alimentación del inversor y disfrutar de la potencia libre.

Instrucciones de uso

Una vez que el sistema ha sido montado, de utilizar la unidad es una brisa. El sistema comenzará a cargar las baterías sin necesidad de que el usuario haga nada. Una vez listo para disfrutar de la potencia libre, simplemente gire el interruptor de encendido del inversor en la posición "on" y conecte el dispositivo eléctrico deseado.

Si por cualquier razón, el lugar de instalación está en una zona en la que hay una pared cercana, árbol u objeto que está obstruyendo el flujo de viento y la creación de una región de alta turbulencia, a continuación, simplemente coloque la manivela en el orificio de la caja de cambios de la torre y arrancar la unidad hasta que tiene llegar a su posición de funcionamiento óptimo.

Instrucciones de mantenimiento

El Sistema Solar y Energía Eólica híbrido fue diseñado para que haya un mínimo de mantenimiento requerido.

Para las operaciones óptimas y por más tiempo de vida del producto, se recomienda lo siguiente:

- Limpiar la cara de los paneles con una toalla mojada cada dos semanas - no rociar agua fría sobre paneles calientes o podría correr el riesgo de arranque ellos!
- Controlar la suciedad o desechos que pueden recoger en ellos, ya que esto puede reducir la eficiencia del sistema
- El montaje y componentes de conexión a tierra deben ser revisados semanalmente por la corrosión y asegurar un montaje firme y seguro.
- Todos los cables y accesorios de conectores deben ser inspeccionados por los daños semanal.
- Limpie el exterior de la torre con una toalla y un limpiador de superficies para que el producto permanece estéticamente agradable.
- Inspeccione la caja de la energía eléctrica por lo menos una vez a la semana para todos los residuos, acumulación de agua, etc. La caja de alimentación eléctrica debe estar libre

de cualquier residuo. Uso y manguera de aire o plumero para limpiar el interior de la caja eléctrica. (El no hacerlo puede anular la garantía del producto).

Especificaciones Técnicas

Tamaño:

- Sistema de Torre (torre, palas, la cola, el panel solar)
  - Diámetro o lámina: 59.25 pulgadas cuadradas aproximadamente
  - Hoja Cabeza Liquidación: 90 en (no extendido) / 144 en (extendido) aproximadamente
  - Sistema Altura total: 149 en (no extendido) / 203 (ampliado) aproximadamente
  - De la cola a la lámina de la cara: 51 en aproximadamente el
- Energía Eléctrica Box: 32 de largo x 19 de ancho x 19 de altura

Peso:

- Sistema de Torre (torre, palas, la cola, el panel solar): 95 libras. aproximadamente
- Energía Eléctrica Box: 120 libras. aproximadamente
- Sistema híbrido de energía eólica solar total y: 215 libras. aproximadamente

Generador - Libertad PMG (generador de imanes permanentes):

- Dimensiones totales:
  - 3/8 "agujeros de los tornillos Diámetro
  - 1-15 / 16 "en el centro, entre los agujeros de montaje
  - 5-7 / 8 "Ancho Diámetro exterior
  - 6-5 / 16 "Tall
- Sxin escobillas
- Núcleo del estator sesgada con acero eléctrico de alto grado y bobinas de cobre de servicio pesado
- Caja de aluminio pulido
- Produce tensión de la batería en aproximadamente 266 RPM
- Produce el doble de la tensión de la batería en aproximadamente 506 RPM
- Los productos manufacturados en los EE.UU.

Panel Solar - Renogy Panel Watt 100 (RNG-100D):

- Dimensiones totales:
    - 47 en la longitud x 21,3 mm Ancho x 1,4 en Altura
- Celda Solar: monocristalino (4.9 x 4.9 in)
- Número de celdas: 36
- Peso: 16.5 libras.
- Marco: aleación de aluminio anodizado
- Conectores: Los conectores MC4
- Potencia máxima en STC (Pmax): 100W
- Tensión de funcionamiento óptimo (Vmp): 18,9 V
- Corriente de funcionamiento óptima (Imp): 5.29
- Tensión máxima del sistema: 600 VDC

Instrucciones de seguridad / Conciencia

- Descargas eléctricas o electrocución si se utilizan mal. Por favor, operar de manera responsable.
- NO use el sistema de energía híbrida en condiciones de humedad, como la lluvia y la nieve, o cerca de una piscina o sistema de rociadores.
- NO haga funcionar la turbina de viento con las manos húmedas. Mantenga la caja eléctrica seca y libre de escombros.
- NO deje el sistema a la intemperie durante las épocas de mal tiempo.
- En caso de una tormenta, almacenar el sistema híbrido en-puertas. Como mínimo, cubra la torre de turbina eólica y los paneles solares y desconecte la caja eléctrica del sistema.
- NO llegar a detener manualmente las palas de aerogeneradores (haciendo así que los resultados de mayo en lesiones corporales, como las cuchillas pueden tener bordes afilados y puede ser que gira a altas velocidades.
- NO intente realizar la instalación de forma individual. Siempre pida ayuda con la instalación de la torre sobre una base.
- Mantenga conectores seco y limpio, y asegurar que las tapas de los conectores son apretado con la mano antes de conectar los módulos. NO intente hacer conexiones con conectores húmedos, sucios o no defectuosos.

* Todas las especificaciones están sujetas a cambios sin previo aviso. Por favor, consulte con su proveedor local para obtener las especificaciones exactas.

* Colores del producto y los accesorios están sujetos a cambios sin previo aviso.

* El fabricante no se hace responsable por los daños de otros dispositivos cuando se conecta a el inversor de la energía eólica y solar híbrido Power System.